FINAL

Duwamish/Diagonal CSO/SD
Cleanup Study Report

Elliott Bay/Duwamish Restoration Program

Prepared for the
Elliott Bay/Duwamish Restoration Program Panel
by
King County Department of Natural Resources and Parks
Anchor Environmental, L.L.C.
EcoChem, Inc.

Panel Publication 30

Elliot Bay/Duwamish Restoration Program
NOAA Damage Assessment and Restoration Center Northwest
7600 Sand Point Way NE
Seattle, WA 98115-0070

(206) 526-6029
FAX (206) 526-6665

October 2005

Individuals and organizations needing further information about the Elliot Bay/Duwamish Restoration Program should contact the Administrative Director at the following address and telephone number:

John Kern, Administrative Director
Elliot Bay/Duwamish Restoration Program
NOAA Damage Assessment and Restoration Center Northwest
7600 Sand Point Way NE
Seattle, WA 98115-0070
(206) 526-6029 FAX: (206) 526-6665

The Panel of Managers holds regularly scheduled meetings that are open to the public. Technical Working Group and committee meetings are scheduled on an as-needed basis, and are also open to the public. Meetings are generally held at the National Oceanic and Atmospheric Administration, National Marine Fisheries Service – Regional Directorate Conference Room, Building 1, 7600 Sand Point Way NE, Seattle. The Panel recommends that you contact the Administrative Director at the above phone number to confirm meeting schedules and locations. The panel also holds periodic special evening and weekend public information meetings and workshops.

General Schedule for Panel and Committee Meeting Dates

Panel: quarterly, first Thursday of January, April, July, and October, 9:30 A.M. – 12:30 P.M.
Habitat Development Technical Working Group: third Thursday of every month, 9:30 A.M. – 12:30 P.M.
Sediment Remediation Technical Working Group: scheduled as needed.
Public Participation Committee: scheduled as needed.
Budget Committee: scheduled as needed.

Environmental Review of Specific Products

Formal hearings and comment periods on appropriate environmental documents for proposed sediment remediation and habitat development projects will be observed. Please contact the Administrative Director for more information.

This information is available in accessible formats on request at (206) 296-0600 (voice) and 1-800-833-6388 (TTY/TDD users only).

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF COMMON ABBREVIATIONS, ACRONYMS, AND TERMS

<MDL	less than Method Detection Limit
<RDL	detected below the Reporting Detection Limit
AET	Apparent Effects Threshold when bioassays show toxicity
armored shoreline	rock covered shoreline
Aroclor	industrial name for polychlorinated biphenyl (PCB)
AWQC	Ambient Water Quality Criteria
B	data qualifier indicating contamination reported in the blank
BMP	best management practices
BNA	Base/Neutral/Acid, part of extractable organic chemistry analysis
CAD	Confined Aquatic Disposal
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
channel area	part of study area located in dredged navigation channel
City	City of Seattle
cm	centimeter
cm/s	centimeter per second
cm/yr	centimeter per year
COCs	Chemicals of Concern relative to sediment cleanup needs
CSL	Cleanup Screening Levels criteria establishes minor adverse effects level
2CSL	Concentrations that are two times the CSL values
CSO	Combined Sewer Overflow
CWA	Clean Water Act
cy	cubic yards
DEA	David Evans and Associates
Diagonal Way CSO/SD	large City stormwater drain plus CSO east of Kellogg Island
Diagonal Ave. S. Treatment Plant	historic sewage treatment plant that discharged east of Kellogg Island
Diagonal Drainage Basin	on east side of Duwamish River adjacent to Diagonal SD
DPS	Distinct Population Segment
Duwamish Avenue South SD	small City stormwater drain east of Kellogg Island
Duwamish CSO	King County emergency CSO outfall east of Kellogg Island
Duwamish Siphon	sewage pipes under the Duwamish River near Kellogg Island
DW	Dry Weight
DWU	Drainage and Wastewater Utility for City of Seattle
E	data qualifier for estimated value
EA	Environmental Assessment
EBDRP	Elliott Bay/Duwamish Restoration Program
EBI	Elliott Bay Interceptor
Ecology	Washington State Department of Ecology
EDMI	Electronic Distance Measuring System
EFH	Essential Fish Habitat
EHW	Extremely Hazardous Waste is a designation that determines disposal options
EPA	U.S. Environmental Protection Agency
EPA data	sediment chemistry for 300 Duwamish River stations sampled in 1998

ESA	endangered species act
E-Shaped Pier	offshore pier of piling clusters previously used by Lafarge Cement
ESU	evolutionarily significant unit
G	data qualifier for low SRM recovery/low surrogate recovery/low MS recovery
GPS	Global Positioning System
GRE	Growth Rate Endpoint for neanthes bioassay test
Hanford Drainage Basin	in Rainer Valley, but connects to Diagonal SD/CSO
HH	Halogenated Hydrocarbons are considered persistent constituents
hot spot	increased chemical concentration in a small geographic area
HPA	Hydraulic Project Approval
HPAH	High Molecular Weight Polycyclic Aromatic Hydrocarbons
HQ	Hazard Quotient is ratio of exposure dose to the no adverse effect dose
I-5	Interstate 5
J	data qualifier for tentatively detected
KCEL	King County Environmental Laboratory
KCDMS	King County Department of Metropolitan Services
KCDNR	King County Department of Natural Resources
km	kilometer
L	data qualifier for high SRM, matrix spike, or surrogate recovery
LAET	Lowest Apparent Effects Threshold
2LAET	Second Lowest Apparent Effects Threshold
low salinity sediments	porewater values between 0.5 and 25 parts per thousand
LPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbons
m	meters
m^3/sec	cubic meters per second
m^2	square meter
marine sediments	porewater salinity greater than 25 parts per thousand
Mass Balance Model	recontamination based on discharge inputs and outputs
MCUL	Minimum Cleanup Level
MDL	Method Detection Limit
MEC	MEC Analytical Systems, Inc.
METSED	modified SEDCAM model used by Metro/King County staff
Metro	Municipality of Metropolitan Seattle
mg/kg	milligrams/kilogram
MGY	million gallons per year
MGD	million gallons per day
MLLW	mean lower low water
MS	Matrix Spike
MUDS	Multi-User Disposal Site
MTCA	Model Toxics Control Act
NAD83	North American Datum for 1983 denotes state plane coordinate grid
NCD	Nearshore Confined Disposal
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
North Inshore Area	part of study area nearest to Duwamish and Diagonal outfalls
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List of contaminated sites leads to Superfund designation

NRDA	Natural Resource Damage Assessment
OC	Organic Carbon normalized value used for certain SMS organic chemicals
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PEIS	Programmatic Environmental Impact Statement
PIE	Pacific International Engineering, PLLC
Phase 1 Sampling	August 1994 surface grabs, bioassays, cores
Phase 1.5 Sampling	November 1995 added surface grabs
Phase 2 Sampling	May, June, July, and Sept 1996 cores, surface grabs, bioassays
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PSAMP	Puget Sound Ambient Monitoring Program conducted by State
PSD	Particle Size Distribution of sediment samples
PSDDA	Puget Sound Dredge Disposal Analysis
PSEP	Puget Sound Estuary Program
PSWQA	Puget Sound Water Quality Authority
PVC	Polyvinyl chloride
QA	Quality Assurance
QA1 Review	Quality Assurance Review
QA/QC	Quality Assurance/Quality Control relative to data generation
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDL	Reporting detection limit
%RSD	percent Relative Standard Deviation for replicate samples
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SD	Stormwater Drain that discharges separated stormwater
SD/CSO	an outfall for both a SD and CSO, with storm water the biggest volume
SEDCAM	model discussed by Ecology for calculating recontamination potential
SEPA	State Environmental Policy Act (for Washington State)
SIZ	sediment impact zone
SMS	Sediment Management Standards prepared by Ecology for Washington State
SMS Bioassay	10-day amphipod, echinoderm embryo, and 20- day neanthes
SMURF	Sediment Multi-User Remediation Facility
South Inshore Area	part of study area south of Duwamish and Diagonal outfalls
SQS	Sediment Quality Standards criteria values establishes no adverse effects level
SRTWG	Sediment Remediation Technical Working Group for EBDRP
SRM	Standard Reference Materials
Study Area	Duwamish River offshore from Duwamish/Diagonal outfalls
TCLP	Toxicity Characteristics Leaching Procedure
TBT	tributylin
TMDL	total maximum daily load
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
TSS	total suspended solids
U	data qualifier for undetected value in sample

USACE	United States Army Corps of Engineers
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WDOE	Washington State Department of Ecology
WDNR	Washington State Department of Natural Resources
X	data qualifier for very low SRM recovery/very low surrogate recovery/very low MS recovery
XHT	data qualifier indicating exceedance of holding time

Executive Summary

The Elliott Bay/Duwamish Restoration Program (EBDRP) was established to implement the requirements of a 1991 Consent Decree defining the terms of a settlement for natural resource damages. The goals of the EBDRP include remediation of contaminated sediment associated with Metro (previously Municipality of Metropolitan Seattle, and now King County Department of Natural Resources [KCDNR]) and City of Seattle (City) combined sewer overflows (CSOs) and storm drains (SDs).

This Cleanup Study Report addresses contaminated sediment associated with the KCDNR Duwamish CSO outfall and the nearby City Diagonal Way CSO/SD outfall (Duwamish/Diagonal outfalls), both of which are either historic or current discharges to the Duwamish Waterway in Seattle, Washington. A small primary treatment plant rated at about 8 million gallons per day (MGD) was operated by the City in 1940-1961 and then by Metro in 1962-1969 and discharged upstream of these outfalls for about 30 years until it was closed in 1969.

Site assessment activities included identification of contaminants of concern, delineation of the extent and magnitude of sediment contamination around the outfalls, as well as evaluations of CSO-reduction measures and watershed source controls within the study area. As part of this effort, KCDNR performed three rounds of sediment sampling and analysis between August 1994 and September 1996. Recontamination modeling based on these data was performed during this period by KCDNR and during mid-1999 by WEST Consultants. Information presented in this report is used to refine the final cleanup area and assist in the selection and design of sediment cleanup alternatives.

Major conclusions of this Cleanup Study Report are:

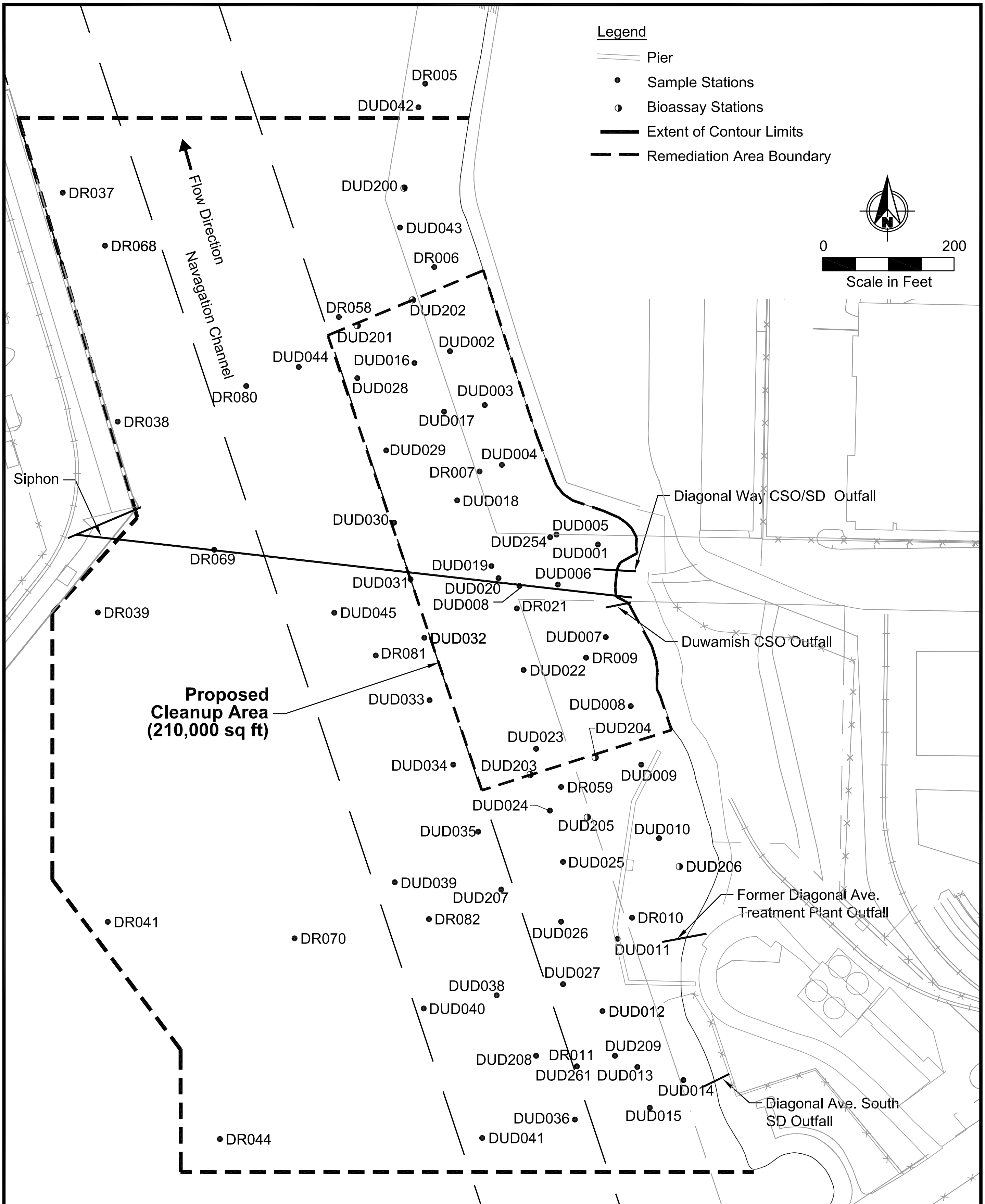
- CSO discharges from the Duwamish CSO outfall are controlled to less than one overflow event per year. None are known to have occurred since 1989. CSO discharges from the Diagonal Way CSO/SD outfall historically exceeded 300 million gallons per year (MGY) and continue to average over twenty events per year with a total annual CSO discharge volume estimated to be about 65 MGY.
- Stormwater currently discharges through the Diagonal Way CSO/SD outfall from both the Diagonal and Hanford drainage basins, with a combined drainage area of 2,585 acres. This outfall contributes a significant quantity of water to the Duwamish River during storm events, with an estimated discharge volume of 1,230 MGY.
- Watershed source control efforts being implemented or planned in the Diagonal and Hanford drainage basins by City Drainage and Wastewater Utility staff include SD sediment removal, business inspections, public education, response to citizen complaints, and tracking the source of a recurrent oil sheen.
- The major chemicals of concern found in sediment in the study area near the Duwamish/Diagonal outfalls are polychlorinated biphenyls (PCBs), mercury, bis (2-

ethylhexyl) phthalate, and butyl benzyl phthalate. A phthalate hot spot is present directly in front of the Diagonal Way CSO/SD outfall, but there is a band of elevated phthalate surface concentrations that extends upstream and downstream. Bioassay testing at stations located 350 to 500 feet from the outfall showed no toxicity to three bioassay tests even though these stations had elevated levels of phthalates.

- A rectangular cleanup boundary was established for the site based on the following conditions: 1) setting the western cleanup boundary to the physical limits imposed by the navigation channel; 2) setting the northern cleanup boundary to stations exhibiting no exceedances of sediment bioassay criteria; 3) setting the southern cleanup boundary to stations exhibiting no exceedances or limited exceedances (less than Cleanup Screening Levels [CSL]) of sediment bioassay criteria; and 4) setting the eastern cleanup boundary to the shoreline. The encompassed area is estimated at 4.8 acres (approximately 210,000 square feet, **Figure ES-1**).
- The depth of sediment contamination is variable. Sediment core data indicate that concentrations exceeding sediment criteria extend to depths of 3 to 9 feet, depending on the particular chemical and core location. In addition, some chemicals (e.g., PCBs) show increasing concentrations with depth near the outfalls.
- Recontamination modeling performed by KCDNR in 1997 (Appendix H) indicated that recontamination by bis (2-ethylhexyl) phthalate from stormwater could occur, but this would be limited to the area near the outfalls.
- A mass balance model by WEST Consultants (1999; Appendix I) suggests that, even with nearly total source control of the phthalate discharges, there would potentially be Sediment Quality Standards (SQS) exceedances produced solely by the background concentrations of phthalates in suspended particulate matter in the study area.
- The data from King County and EPA studies indicate a localized area of PCBs in the general Duwamish/Diagonal study area. This localized area suggests using PCBs as the primary chemical of concern rather than phthalates. PCBs are primary chemicals of concern for the Duwamish River sediment because these chlorinated compounds bioaccumulate in organisms and represent both human health and ecological risks. Removal of PCB hot spots in sediment is a priority for regulatory agencies and the tribes.
- Current discharge pipes are not a significant source of PCBs.
- The greatest threat of PCB recontamination in the study area is from potential dredging activities that disturb and mobilize existing PCB-contaminated sediments. Efforts should be made to minimize recontamination potential by coordinating when and how dredging projects are carried out in this section of the river.
- The 4.8-acre area in front of the Duwamish/Diagonal outfalls was selected as the proposed remediation site for the EBDRP program and does not include a chemical hot spot located upstream near the former Diagonal Avenue Treatment Plant outfall. That area will be addressed under future Superfund activities in the lower Duwamish River.

- Site constraints affecting cleanup feasibility were enumerated, and a screening-level natural recovery/recontamination model was run for PCBs. The model indicated that natural recovery would not occur in an acceptable time frame (10 years), dredging could release contaminated sediments, and that cleanup would accelerate recovery to below the SQS within a 5 to 10 year period.
- Potential remedial technologies were screened and appropriate technologies were combined into remedial alternatives. The alternatives were then evaluated and compared, with a dredging and capping alternative that results in no change to existing elevations selected as the preferred alternative.
- The preferred alternative will remove 42,500 cubic yards (cy) of sediment with a clamshell dredge and send it to an off-site facility; the exact facility is not yet determined. Following dredging, the remediation site will be capped with clean backfill material (42,500 cy) to isolate remaining sediment contamination from the environment. The final design will utilize U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (EPA) guidance documents for designing isolation caps.
- Compliance monitoring will be performed following the completion of the remedial action to ensure the continued effectiveness of the cleanup remedy.
- The preferred alternative was preliminarily identified as the option that uses permanent solutions to the maximum extent practicable.

After the draft Cleanup Study Report selected a preferred alternative, public comments were taken into account to modify the cleanup analysis and/or preferred alternative presented herein. During the comment period, concern was raised about potential PCB recontamination of the proposed 5-acre cleanup site by future dredging to remove a localized PCB hot spot located upstream. The EBDRP Panel authorized expanding the cleanup site to include another 2 acres to remove the PCB hot spot area using the same remediation method proposed for the original 5-acre site. Before the Washington State Department of Ecology (Ecology) and EPA would approve an expanded cleanup project they requested information from King County which has been provided in three documents added to the appendices of this finalized Cleanup Study Report. **Appendix R**, *Expanded Area For Duwamish/Diagonal Cleanup Project*, provides details of the expanded project. **Appendix S**, *Source Control Summary Document for Duwamish/Diagonal Sediment Cleanup Project*, describes all source control activities to reduce potential recontamination. **Appendix T**, *Responses to Reviewer Comments on Draft 2001 Duwamish/Diagonal CSO/SD Cleanup Study Report*, provides responses to reviewer comments.



EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure ES-1
	Final Focus Area	

K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-37.dwg FIG ES-1

Sep 28, 2005 2:29pm cdavidson

1.0 INTRODUCTION

This Cleanup Study Report characterizes the spatial extent and significance of chemical contamination detected in sediment near the King County Duwamish Combined Sewer Overflow (CSO) and the City of Seattle Diagonal Way CSO/storm drain (SD) outfall (Duwamish/Diagonal outfalls), located in the Duwamish River. Data from the sediment chemistry characterization of the site are provided in **Appendix A**. Information presented in this report will be used to finalize a cleanup area and assist in the selection and design of sediment cleanup alternatives. This Final Cleanup Study Report is issued consistent with Washington State Sediment Management Standards (SMS), Chapter 173-204 Washington Administrative Code (WAC).

1.1 PROJECT OVERVIEW

To implement the requirements of a 1991 Consent Decree defining the terms of a settlement of alleged natural resource damages, the Elliott Bay/Duwamish Restoration Program (EBDRP) was established. Program oversight is provided by the EBDRP Panel, which is composed of federal, state, and tribal natural resource trustees, the Municipality of Metropolitan Seattle (Metro, which subsequently became part of King County government and is now the King County Department of Natural Resources [KCDNR]), and the City of Seattle (City). The goals of the EBDRP include remediation of contaminated sediment associated with KCDNR and City CSOs and SDs, and restoration of habitat in Elliott Bay and the Duwamish River.

In 1992, a Sediment Remediation Technical Working Group (SRTWG) was established by the EBDRP Panel to address contaminated sediment issues. The SRTWG identified 24 potential sediment remediation sites associated with KCDNR and City CSOs and SDs. These sites were evaluated against several criteria, which included extent of contamination, degree of source control near sites, and public input, as reported in the *Final Concept Document* (EBDRP 1994a). Ultimately, the SRTWG selected three sites (the Duwamish CSO outfall and Diagonal Way CSO/SD; the Norfolk CSO; and the Seattle Waterfront) for further investigation. This Cleanup Study Report addresses only the Duwamish CSO outfall and the Diagonal Way CSO/SD outfalls, which were combined into one site due to their proximity (i.e., the Duwamish/Diagonal outfalls).

In 1994, the *Duwamish/Diagonal Cleanup Study Plan* was prepared by KCDNR (then Metro) on behalf of the EBDRP Panel. The five documents that comprise the Plan are the *Workplan* (EBDRP 1994b), the *Sampling and Analysis Plan* (EBDRP 1994c), the *Phase 2 Sampling and Analysis Plan* (EBDRP 1996a), the *Health and Safety Plan* (EBDRP 1994d), and the *Public Participation Plan* (EBDRP 1994e). These plans provide the framework for the Duwamish/Diagonal sediment cleanup study.

The 1994 *Workplan* identified nine chemicals or classes of chemicals of potential concern based on six preliminary sediment samples collected in 1992 near the outfalls (**Appendix B**, Pre-Phase 1 Data). The chemicals of concern (COCs)exceeding SMS sediment quality criteria were mercury, silver, chlorinated benzenes, phthalate acid esters, polychlorinated biphenyls (PCBs), high molecular weight polycyclic aromatic hydrocarbons (HPAHs), and benzoic acid.

KCDNR implemented field collection activities, described in the *Sampling and Analysis Plan*, between August 1994 and September 1996. The primary goal was to determine the extent of sediment contamination around the Duwamish/Diagonal outfalls based on comparison to SMS criteria. Sediment chemistry data collected by U.S. Environmental Protection Agency (EPA) in 1998 for a National Priority List evaluation were also used to define areas exceeding SMS for four specific chemicals: PCBs, mercury and two phthalate compounds. Sediment recontamination modeling, to assess whether sediment cleanup could lead to long-term SMS compliance, was undertaken as part of this assessment and ultimately considered two different methodologies. The results of these efforts are presented in this report.

1.2 REPORT ORGANIZATION

This report is organized into nine main sections:

- **Chapter 1** provides a project overview.
- **Chapter 2** describes the environmental setting and natural resources of the project area.
- **Chapter 3** presents a source control evaluation, including identification of contaminant sources, completed CSO reductions, and potential for sediment recontamination based on modeling results.
- **Chapter 4** describes the data collection efforts and chemical results associated with the cleanup study including sampling and testing methods, quality assurance review results, sediment chemistry results, sediment bioassay results, and waste disposal characteristics.
- **Chapter 5** presents the data interpretation including comparison to SMS criteria, evaluation of concentration gradients, comparison to upgradient concentrations, identification of COCs, potential for contaminant migration and fate, and determination of the area to be evaluated further.
- **Chapter 6** outlines the applicable laws and regulations pertaining to cleanup actions at the site.
- **Chapter 7** identifies the range of known available technologies and process options capable of achieving remediation of the contaminated sediments at the Duwamish/Diagonal outfalls.
- **Chapter 8** assembles, screens, and develops alternatives from the technology types and process options retained from Chapter 7.

- **Chapter 9** evaluates the alternatives against eight criteria presented in WAC 173-204-560(4)(f)(iii) and selects the preferred alternative.

2.0 SITE DESCRIPTION

2.1 PROJECT LOCATION

The Duwamish/Diagonal Study Area (Study Area) is located at approximately river kilometer (km) 3 in the lower portion of the Duwamish River, within the south industrial section of Seattle, Washington (**Figure 2-1**). The Duwamish/Diagonal outfalls are located on the east side of the Duwamish River, upstream of Harbor Island and immediately downstream of Kellogg Island.

The Diagonal Way CSO/SD outfall is located south of Port of Seattle's Terminal 106 at the South Oregon Street unimproved right-of-way (**Figure 2-2**). This outfall has a large concrete discharge structure for the 144-inch diameter pipe, which is totally exposed at -3 feet mean lower low water (MLLW). The 36-inch diameter Duwamish CSO outfall is submerged and discharges in the waterway approximately 30 meters (m) (100 feet) south of the Diagonal Way CSO/SD outfall.

The Study Area includes the offshore area surrounding the two outfalls. In addition, two outfalls located within 1,000 feet upstream (the former Diagonal Way Treatment Plant outfall and the Diagonal Avenue South SD outfall) are included in the Study Area to evaluate upstream conditions.

2.2 ADJACENT LAND USE AND PROPERTY DESCRIPTIONS

Land use in the vicinity of the Study Area is primarily industrial (**Figure 2-2**). A railroad yard is located approximately 0.7 km east of the Duwamish/Diagonal outfalls. The Port of Seattle's Terminal 106 container facility is located north (downstream) of the outfalls, and the Port of Seattle's Terminal 108 container facility is located just south of the outfalls. Only a portion of Terminal 108 is paved and the eastern part is used for container storage. Seattle City Light has an easement for the power transmission lines located along the South Oregon Street right-of-way, and these lines cross the Duwamish River just north of the outfalls. From 1989-1999, the LaFarge Corporation operated a cement plant southeast of the Duwamish/Diagonal outfalls. A large Washington State Liquor Control Board warehouse is located approximately 90 m northeast of the outfalls.

Shoreline in the vicinity of the Study Area has been designated as Urban Industrial (special designation for water-dependent use), Conservancy Preservation, and Conservancy Recreation (conditional and special use for habitat enhancement; PTI 1993). Shoreline uses include cargo transfer, industrial warehousing, barge repair, habitat restoration, and tribal and recreational fishing. Submerged lands in the Duwamish Waterway are owned by the City and the Port of Seattle (**Figure 2-3**).

2.3 SHORELINE FEATURES AND BATHYMETRY

The intertidal area in the vicinity of the outfalls is generally riprapped, except for a small pocket beach located just north of the Diagonal Way CSO/SD outfall. Below the riprapped shoreline, the lower beach is composed of sand with cobble. Directly in front of the Diagonal Way CSO/SD outfall, a flocculent mud delta has developed.

Bathymetry surveys were conducted in the Study Area in 1992, 1994, 1996, and 1997. Dredging to create the original shipping channel produced the steep slopes that define the riverbanks in this stretch of the waterway. Water depth in the Study Area ranges from about +13 feet above MLLW at maximum high tide to a dredged depth of -30 feet below MLLW in the channel (**Figure 2-4**). An intertidal delta extends into the river in front of the Diagonal Way CSO/SD outfall. Bathymetry data show that downstream of the outfalls, the river bottom slopes evenly from the shore toward the middle of the river.

Upstream of the outfalls, the bottom slopes steeply from the shore to a depth of 16 to 18 feet and then flattens out for approximately 200 feet before sloping steeply again toward the middle of the river. This large area of flat bottom topography upstream of the outfalls was created in 1977 when Chiyoda Corporation dredged the area to create a loading dock facility (**Figure 2-5**). As part of this project, the shoreline between the Diagonal Way CSO/SD outfall and the outfall for the former Diagonal treatment plant was excavated and moved east about 30 m (100 feet). The contaminated dredged material was placed upland on the old treatment plant site. A 1976 aerial photo (Figure C-3, **Appendix C**) shows the shoreline before modification and clearly shows the two settling ponds that were built at the north end of the treatment plant property to contain PCB contaminated sediments dredged from Slip 1 in 1976. A 1977 aerial photo (Figure C-4, **Appendix C**) shows the shoreline modified and the entire treatment plant property leveled leaving no sign of the two settling ponds or the old sludge lagoons. Permit applications indicate that the excavated sediments were to be used as fill along the new shoreline and other parts of the old treatment plant site. Chiyoda's proposal for a shore-based dock was denied during permit application and the E-shaped pier near the former Diagonal Avenue Treatment Plant outfall was installed offshore (**Figure 2-4**).

During installation of the Diagonal Way CSO/SD outfall, the Duwamish CSO outfall, and the Duwamish Siphon sewer lines in 1965-1967, sediment was dredged and backfilled near the outfalls and across the waterway. The siphon pipes (42-inch and 21-inch diameter pipes) were buried in a trench that was dredged across the river bottom. Detailed bathymetry contours in the Study Area (**Figure 2-6**) show that inshore of the east channel line there is a depression approximately 150 feet wide near the siphon line, suggesting that the area was not backfilled to its original depth. As part of the contract to install the siphon, the City installed the 12-foot diameter Diagonal storm drainpipe and the large rectangular outfall structure in 1965-1967. **Table 2.1** provides a listing of historic property ownership and construction activities in the Study Area. In the navigation channel, the top of the siphon is at an elevation of about 46.5 feet below MLLW, while the channel depth is specified to be -30 feet MLLW.

Table 2.1 HISTORY OF PROPERTY OWNERSHIP AND CONSTRUCTION ACTIVITIES NEAR SITE

Year(s)	Details
1940-1961	City of Seattle builds and operates Diagonal Avenue Sewage Treatment Plant with outfall along east bank of the Duwamish River and capacity to treat about 8.0 million gallons per day (MGD)
1962-1969	Metro takes over operation of Diagonal Avenue Sewage Treatment Plant performing extensive remodeling initially to provide better operational flexibility and efficiency until the plant is closed in 1969.
1966-1997	Metro builds twin buried siphon lines (21- and 42-inch) across the river, which are called the Duwamish Siphon, and on the east shore includes a submerged CSO overflow pipe called the Duwamish CSO (Siphon plans dated 6/65 with as built stamp dated 5/31/67). The Duwamish Siphon transports flow from West Seattle to the Duwamish Pump Station that is being constructed on the east side of the river.
1966-1967	City of Seattle completes installation of Diagonal storm drainpipe along north side of former treatment plant property and includes the large rectangular Duwamish CSO/SD outfall structure on the east river bank. Prior to pipe installation, a slough existed along the north side of the property and received the untreated sewage discharge from a small sewer system located to the northeast. The Diagonal Way CSO/SD outfall and the submerged Duwamish CSO outfall are about 100 feet apart and were constructed under the same contract.
1967	Port of Seattle dredges on west side of river along the face of Terminal 105, which starts at the west side of the Duwamish Siphon crossing and extends downstream about 700 feet (150,444 cy was maximum quantity permitted).
1968	U.S. Army Corps of Engineers (USACE) dredges easterly one half of navigation channel in area just upstream of Duwamish Siphon and extending upstream to past the north end of Kellogg Island (between USACE stations 51 - 60 with 7,000 cy maximum quantity permitted).
1968	Metro completes construction of Elliott Bay Interceptor (EBI) along east side of Duwamish River to transport sewage flow to West Point Treatment Plant that started operation in 1964.
1969	Metro begins operation of the newly constructed Duwamish Pump Station, which receives flow from the south through the EBI and from the west through the Duwamish Siphon. The pump station lifts these flows for gravity transport north in the EBI.
1969	Metro closes Diagonal Avenue Treatment Plant and all flows are directed to the EBI.
1970	Port of Seattle makes a major change in the east riverbank north of the Diagonal Way CSO/SD when they install a long rock bulkhead in the river and backfill the site to create about 900 linear feet of new river front property that is now the Terminal 106 property.
1974	There is a documented PCB spill of about 255 gallons of Aroclor 1242 into Slip 1 when an electric transformer was dropped and broken on the north pier of Slip 1 on September 13, 1974. Initial dredging activities in Slip 1 recovers an estimated 80 gallons of the spilled PCBs.
Mid 1970's	Chiyoda Corporation buys the old Diagonal Avenue Treatment Plant site and plans to build a shore-based loading dock facility along the riverbank.
1975	USACE negotiates with Chiyoda Corporation to allow PCB contaminated dredged spoils to be placed in two pits excavated in the old sludge ponds located on the north end of the former treatment plant property.

Year(s)	Details
1976	USACE conducts second dredging for PCBs at northwest corner of Slip 1 using hydraulic dredging to settling ponds on Chiyoda property. They estimate that the dredging removed another 170 gallons of the 255-gallon spill of Aroclor 1242 resulting in a total recovery of 98 percent.
1977	Chiyoda Corporation dredges a berthing area making a major change in the east shoreline in the area between the Diagonal Siphon and the former Diagonal Avenue treatment plant outfall. The shoreline is moved east about 100 feet and the nearshore area deepened, which likely removes historic contaminated bottom sediment. The estimated 80,000 cy of dredge material is used to fill the nearshore area, the holding ponds, and to level the former treatment plant site. Chiyoda is denied a permit to build a shore-based dock facility so the project ends without a dock.
1984	USACE dredges shoal of contaminated sediment from the channel near the former Diagonal Avenue treatment plant outfall and removes about 1,100 cy of contaminated sediment. The disposal for these contaminated sediments involves depositing them in a depression in the bottom of the West Waterway and covering them over to an average depth of about 2 feet with about 4,200 cy of clean sand dredged from the upper turning basin.
1985	Port of Seattle purchases former Diagonal Avenue treatment plant property from Chiyoda Corporation and subdivides property into two lots. Lot B is located along the river and Lot A is located farther east away from the river. Chevron Corporation purchases Lot A at this time, but they later deed the property back to the Port in 1992.
1989	On Lot B, the Port of Seattle develops Terminal 108 and LaFarge Corporation uses the site for bulk dry cement receiving, storage, and trans-shipment. An offshore pier consisting of piling clusters is installed in the river near the abandoned outfall of the former Diagonal Avenue treatment plant.
1989	Port of Seattle constructs a 1.1 acre public shoreline access site at the street end of Diagonal Avenue as mitigation for installing riprap improvements on the shoreline upstream (south) of the abandon outfall of the former Diagonal Avenue treatment plant.
1992	Port of Seattle obtains Lot A from Chevron Corporation and uses all of the property for an expanded container storage facility connected with Terminal 106 to the north.
1994	On January 1,1994, Metro merges with other King County departments and King County assumes ownership of all former Metro sewer collection systems, treatment plants, and CSO facilities.
1998	LaFarge Corporation closes the bulk dry cement receiving, storage, and trans-shipment site. Port of Seattle removes all land-based structures including the conveyor system to the pier. The pier remains and the property is currently for lease.

It appears the backfill material used to cover the Siphon pipes in 1966-1967 may have been contaminated with PCBs because core samples collected near the Siphon alignment have elevated PCBs extending down to the deepest core section (6-9 feet). The original source of the PCB contamination in the backfill material is not known. Two potential historic sources of PCBs to this part of the river are: 1) a wastewater drainage slough that entered the river about where the Diagonal Way CSO/SD outfall was constructed in 1967; and 2) the old treatment plant outfall located upstream (operated from 1940-1969).

2.3.1 Navigation

The lower 9.6 km of the Duwamish River is maintained as a navigable waterway by the U.S. Army Corps of Engineers (USACE). In the Study Area, the navigation channel is delineated by straight, parallel lines, generally aligned with the shore. The eastern side of the navigation channel is approximately 250 feet from the east bank of the river in the vicinity of the outfalls. The navigation channel is approximately 60 m (200 feet) wide and about 9 m (30 feet) deep (below MLLW; Weston 1993). According to USACE bathymetry, depths in the navigation channel range from 26 to 35 feet (all depths MLLW). Most of the channel was dredged prior to 1960, but a portion immediately upstream of the site was dredged in 1968 (Tetra Tech 1988). The navigation channel is intended to be maintained at a depth of 30 feet; however, a 50-foot wide and more than 1,200-foot long shoal has developed along the east side of the waterway across from Kellogg Island (**Figure 2-4**). The northernmost portion of the shoal extends approximately to the Duwamish/Diagonal outfalls. Eventually, dredging of this area will be required to maintain the channel.

In 1984, the USACE conducted an emergency dredging action directly off the old treatment plant outfall to remove a shoal that had reduced the navigation channel depth down to -25 feet instead of the required -30 feet depth. The USACE removed one barge load of contaminated sediment to restore the channel depth. Detailed bathymetry from 1994 (**Figure 2-6**) shows "U" shaped contour lines located near the east channel line offshore from the old Diagonal Avenue treatment plant outfall on surveys from 1992 and 1994 indicating that the USACE dredging extended slightly east of the east channel line. The source of this rapidly appearing shoal was not investigated at the time, but the volume of contaminated sediment is too large to be from an accidental barge dump. Close inspection of the detailed contour lines (**Figure 2-6**) shows that the 1977 dredging project created a small ridge of sediment on the upstream side of the old treatment plant outfall. If part of this narrow ridge of contaminated sediment was unstable and slid off into the channel in 1983, it could have produced the type of shoal that the USACE had to remove in 1984.

2.4 WATER RESOURCES

2.4.1 Duwamish River

The Duwamish River begins at the confluence of the Black and Green Rivers at approximately river km 19. The Duwamish/Diagonal Study Area is located at approximately river km 3. The Duwamish River is a salt-wedge estuary, with tides influencing the river over its entire length (Dexter et al. 1981). The mean tidal range in the lower 7 km of the Duwamish River is approximately 2.3 m. The distance upstream to the toe of the salt wedge (salinity at least 25 parts per thousand [ppt]) depends on the tidal amplitude and freshwater discharge. At high tide during periods of low flow, the salt wedge has extended upstream to approximately river km 16. Conversely, at low tide during periods of high flow the wedge has extended only to river km 6.4 (Santos and Stoner 1972). Little mixing of the salt wedge and river water occurs except in the lower 6 km when discharge rates are low (Dexter et al. 1981). The salinity of the upper river water layer increases in the downstream direction, but the salinity of the bottom layer remains fairly constant, except at the toe of the salt wedge (Santos and Stoner 1972).

The Duwamish River at the Study Area ranges from partly mixed to well stratified for low to high discharges, respectively. The thicknesses of the fresh and saltwater layers vary with tides and the river discharge. The salinity at a given depth is generally stable laterally, but can vary with depth between 2 to 28 ppt (Santos and Stoner 1972). Salinity in the main channel sediments is closer to marine conditions because of the stability of the salt wedge in the deeper channel.

River flow is regulated upstream on the Green River by the Howard Hansen Dam. The annual average river discharge is 47 cubic meters per second (m^3/sec) and the probable maximum flood is approximately 400 m^3/sec. The annual suspended sediment discharge from the Duwamish River was estimated to be 1,700 metric tons per year, based on daily measurements of suspended sediments in the mid-1960s (Dexter et al. 1981). Recent data collected for the Elliott Bay Waterfront Recontamination Study (EBDRP 1995) and records for the 1943-1983 period indicate an average Duwamish River total suspended solids (TSS) load of 7,600 metric tons per year. The lower Duwamish River tends to be a depositional zone with deposition rates estimated to be on the order of 5 centimeters (cm)/year in the Study Area (Harper-Owes 1983). More recent data indicate that the sedimentation rate near Harbor Island is between 1 and 1.5 cm/year (EVS 1996).

In a University of Washington study at the Duwamish/Diagonal Study Area, tidal velocities were measured to assess the likelihood of sediment erosion (Dail 1996). The results of that study are inconclusive. Maximum velocities of 30 centimeters per second (cm/s) were measured at the sampling location, 50 cm above the riverbed. Based on sediment samples at the site, a critical velocity (the velocity at which erosion would begin to occur) of 16 cm/s was estimated. Since observed velocities were higher than this critical velocity, erosional events were expected during the monitoring period. However, field observations did not provide evidence of erosional events. Hence, the results of this study are inconclusive.

2.4.2 Surface Water Drainage and CSOs

The lower reaches of the Duwamish River in the Study Area have been heavily modified by human activity. Surface water drainage patterns in the original watersheds have generally been replaced by public and private drainage systems designed to route water away from commercial, residential, and industrial properties and into either piped drainage systems or the remaining wetlands.

Surface drainage and sewage (from CSOs) can enter the Duwamish River in the vicinity of Study Area from three discharge pipes; however, only the first one is a significant source:

- Diagonal Way CSO/SD outfall (144-inch diameter)
- Duwamish CSO outfall (36-inch diameter, no overflows since 1989)
- Diagonal Avenue South SD outfall (18-inch diameter)

The locations of these sources and other relevant features are shown in **Figure 2-2**.

The Diagonal Way CSO/SD outfall is located south of the Port of Seattle's Terminal 106 at the South Oregon Street unimproved street right-of-way. This outfall contributes a significant quantity of water to the river during storm events, estimated at 1,230 million gallons per year (MGY). The 144-inch diameter outfall receives CSO and stormwater flows from both the Diagonal and Hanford drainage basins (**Figure 2-7**). Most City and King County CSO points that can discharge into the stormwater system have been controlled by separation and storage to occur less frequently than one overflow event per year. However, recent information has determined that the King County Hanford #1 CSO is not totally controlled, and is estimated to discharge about 65 MGY out of the Diagonal Way CSO/SD outfall (Swarner personal communication 1999). The Diagonal and Hanford drainage basins have a combined drainage area of about 1,583 acres. Due to the industrial and commercial nature of sections of these basins, there is a significant amount of impervious surface area. Stormwater runoff to the system originates from Interstate 5 (I-5) between mile marks 156 and 163, the Central District, the Rainier Valley, the Duwamish industrial area, and residential Beacon Hill (City of Seattle 1996). The Seattle Drainage and Wastewater Utility (DWU) data are included as **Appendix D**. The Diagonal drainage basin is located on the east side of the Duwamish River adjacent to the outfall. Land use in the basin is predominantly commercial and industrial west of I-5 and residential east of I-5 (City of Seattle 1996). The Hanford drainage basin is located in the Rainier Valley; stormwater flows are transported to the Diagonal Way CSO/SD outfall via the Hanford tunnel. In addition to runoff from the Diagonal and Hanford Basins, stormwater from Terminal 106 is carried by a Port of Seattle drain to the Diagonal Way CSO/SD outfall pipe. This Port of Seattle drain previously discharged into a small cove downstream of the Duwamish/Diagonal outfalls. Additional outfall information is included in **Appendix E**.

The Duwamish CSO outfall enters the Duwamish River roughly 30 m (100 feet) south of the Diagonal Way CSO/SD outfall. Flows that have the potential to discharge from the Duwamish CSO originate on the west side of the Duwamish Waterway from the Delridge Trunk Sewer, the Chelan Avenue Regulator Station, and the East Marginal Way Pump Station. The flow is routed to the West Duwamish Interceptor and then to the siphon forebay. The flow is carried east under the waterway through a siphon of two pipes to the siphon aftbay on the east shore. The flow then travels to the Elliott Bay Interceptor via the Duwamish Pump Station. Outfall pipes are connected at both the siphon forebay and the siphon aftbay structures. The 36-inch diameter Duwamish CSO outfall originates at an overflow structure near the siphon aftbay. Due to the configuration of the Duwamish CSO outfall, overflows are highly unlikely (EBDRP 1994b). The Duwamish CSO outfall is not known to have overflowed during the period from 1989 to the present; furthermore, no overflows are anticipated in the future except under emergency conditions. Additional outfall information is included in **Appendix E**

The Diagonal Avenue South SD outfall is located 300 m (approximately 1,000 feet) south (upstream) of the Duwamish/Diagonal outfalls. The 18-inch diameter drain is attached to a concrete slab located in the upper intertidal area of the sloping shoreline. The drain receives runoff from a 12-acre drainage basin south of the Duwamish/Diagonal outfall between East Marginal Way and the Duwamish River and to the north of Diagonal Avenue South (Tetra Tech 1988). Most of the drainage area is paved and apparently has been used for storage by the surrounding properties (Tetra Tech 1988). This outfall serves an area comprising less than 1 percent of the areas served by the Diagonal Way CSO/SD outfall.

2.4.3 Groundwater Drainage

The Duwamish Valley is located in the central Puget Sound lowland physiographic province. The geology of the area is characterized (from depth to surface) as regional bedrock, glacial erosion and deposition, and fluvial deposition by the Duwamish River. Groundwater flow rates and direction in the vicinity of the Study Area are expected to be complex because of the presence of a filled river channel to the east of the existing river channel. Fill depth near the Study Area is generally 3 to 6 m. The fill is predominantly silt and silty sand. Fine and medium sand with silt lenses underlies the fill (Sweet, Edwards & Associates and Harper-Owes 1985). The Sweet, Edwards & Associates Study reports a typical hydraulic conductivity in the surficial material of 0.01 cm/s and a hydraulic gradient of 0.0037 feet per foot. Using Darcy's Law, with a conservatively large saturated thickness of 15 m in hydraulic communication with the river, the groundwater flow towards the river would be approximately 0.005 m^3/s per km of channel. This flow is very small compared to the riverine and tidal flows and would generally only be of concern if the groundwater were very contaminated. Site-specific groundwater data for a property adjacent to the study area is presented in **Section 3.2.7** and indicates that groundwater in this area would not pose a risk to aquatic receptors in the waterway.

2.5 ECOLOGICAL RESOURCES

2.5.1 Habitat

As part of the Duwamish/Diagonal Site Assessment, biologists from Pentec Environmental, Inc. performed two visits to the Study Area to observe existing habitat conditions. During the July 29, 1996, site visit, seven transects were established along the eastern shoreline of the Study Area. At each transect, qualitative information was collected for substrate type, community dominants, macroinfauna, and slope and bank height. Field observations are summarized below, and detailed memos and transect profiles are included in **Appendix F**.

The entire visible intertidal area downstream of the E-shaped pier is generally riprap constructed in about 1977 during a shoreline excavation to make a berthing area (Figure C-4, **Appendix C**). At mid-to-lower intertidal elevations, the riprap and pilings support a typical epibiota dominated by barnacles (*Balanus glandula*), mussels (*Mytilus trossulus*), and rockweed (*Fucus gardneri*). Large numbers of mussels of reasonable size (30 to 50 mm) may comprise the most probable pathway for contaminant accumulation by a species that could be consumed by humans.

At transect 7 (located halfway between the upstream E-shaped pier and the Duwamish/Diagonal outfalls), the substratum consists of ballast rock from the high water mark out to 9 feet on the transect. The major portion of the slope is armored with riprap at a slope of 30 degrees. A band of sand and clay was exposed at the water's edge below the toe of the riprap. The hard substratum was covered with seaweeds (extensively with *Fucus*, some *Enteromorpha*, and *Mastocarpus*). Just upstream of the Diagonal/Duwamish outfalls the hardrock substratum community was well established on the rocks, the slope appeared steeper here (35 degrees) and was armored with large riprap.

Directly in front of the Diagonal/Duwamish outfalls, a very soft, flocculent mud delta was present, with a strong hydrogen sulfide/hydrocarbon odor. The sediment appeared anoxic with hydrocarbon seeps present on the surface. No evidence of an infauna community was observed.

In association with this project, the City has conducted source control investigations to identify the source(s) of the petroleum discharging from the Diagonal outfall. Seattle DWU source investigation data are included in **Appendix D**.

Just downstream (north) of the Diagonal outfall, a small pocket beach supports a good infauna with abundant polychaetes and oligiochaetes. Shore crabs (*Hemigrapsus oregonensis*) were common under cobbles on the beach but no clams were found. The beach slope downstream of the pocket beach consisted of a heavily armored riprap slope of 45 degrees with a *Fucus* dominated community. This long section of armored shoreline was constructed in 1970 as part of the Port of Seattle development of Terminal 106 (Figure C-2, **Appendix C**).

A good opportunity for large-scale habitat enhancement may exist in the area just upstream (south) of the Duwamish outfall. The uplands behind the top of the riprapped shoreline are currently unused and contain an early successional scrub shrub. If this property were available, the shoreline could be cut back substantially, thus adding habitat area in selected intertidal elevations. The middle and lower beach could be resurfaced with a silty sand, and the upper intertidal area planted with a fringe of saltmarsh vegetation.

2.5.2 Fish and Wildlife

The following information has been compiled from various sources and represents fish and wildlife species observed in the Duwamish/Green River basin and various portions of the Duwamish estuary. Not all of the species discussed below may actually use the Study Area.

Fish habitat in the Duwamish estuary is generally limited and significantly degraded by the armoring of the riverbanks and urban/industrial development (USACE 2000). Despite the habitat limitations, the Duwamish estuary provides nursery habitat for numerous marine fish species and juvenile salmonids. The small tributaries that feed into the lower Green River from the surrounding foothills still have some areas of good-quality fish habitat that is used primarily by coho for spawning and rearing (USACE 2000). Anadromous fish using these habitats are expected to migrate through the Duwamish estuary on their way to marine waters and back to the river for spawning.

Studies conducted in the lower Duwamish River have identified more than 20 fish species (Parametrix 1980; Warner and Fritz 1995) in the Green/Duwamish River. These fish species include both anadromous and marine stocks and are detailed below.

2.5.2.1 Anadromous Fish Species

Six species of salmonids inhabit the Green-Duwamish basin including chinook salmon, coho salmon, chum salmon, steelhead, sea-run cutthroat trout, and dolly varden/bull trout (Williams et al. 1975). The Duwamish estuary is an important habitat area for juvenile salmonids because it provides food and physiological refuge. Juvenile salmonids prey preferentially on certain species of crustaceans including amphipods, some species of harpacticoid copepods, cumaceans, opossum shrimp, and midges (USACE 2000). These species are typically found on mudflats, similar to those present in the Duwamish estuary. The lower 10 to 13 km of the Duwamish estuary is an important transition zone for juvenile salmonids to acclimate to saltwater

(Parametrix 1980). The Duwamish/Diagonal outfalls are located within this transition zone at river km 3 and may provide additional feeding areas for fish.

The National Marine Fisheries Service (NMFS) has identified the Puget Sound evolutionarily significant unit (ESU) of chinook salmon as threatened and the Puget Sound/Strait of Georgia ESU of coho salmon as a candidate species for listing under the Endangered Species Act (ESA). Critical chinook habitat, including all accessible marine, estuarine, and river reaches in Puget Sound, is also protected under the act. Additionally, the United States Fish and Wildlife Service (USFWS) has identified the Puget Sound distinct population segment (DPS) of bull trout as a threatened species under the ESA. More specific information for ESA-listed and candidate anadromous species is given below.

Chinook salmon: The Duwamish/Green River basin summer/fall chinook are distinguished from other Puget Sound chinook stocks by geographic distribution (WDFW et al. 1994). As with other Puget Sound summer/fall stocks, spawning occurs from mid-September through October. In general, there are two types of chinook salmon: ocean-type and stream-type. Ocean-type are more common south of 56^{o} N latitude (i.e., in the continental United States; Healey 1991). This type of fish migrates to the estuary during the first year, typically within three to four months after emergence (Healey 1991). Juvenile survival is heavily dependent on the estuarine and nearshore conditions like those found in the Duwamish estuary. Studies have shown that, of the five Pacific salmon species, chinook salmon are most dependent on estuaries during the early stages of their life cycle (Varanasi et al. 1993). Juvenile chinook salmon leave the river environment and migrate to the ocean beginning in early April and extending until mid-July (Williams et al. 1975). Juvenile chinook salmon were found to be most abundant near Kellogg Island between April and June (Parametrix 1982). Primary prey groups for chinook juveniles in estuaries include benthic amphipods, chironomids, mysids, copepods, and aquatic insects (Nightingale and Simenstad 2001). Ocean-type chinook salmon generally spend most of their marine migrations in coastal waters and return to their natal river in the fall, a few days or weeks before spawning.

Coho salmon: The Duwamish/Green River basin coho stocks utilize, to some degree, almost all of the accessible tributaries in the area. Coho returning to this system typically enter freshwater from mid-September to mid-November and spawn from late October to mid-January, with some variation observed between streams and between years within streams (WDFW et al. 1994). Coho juveniles generally remain within their natal stream systems for more than a year, migrating to sea early in their second year of freshwater life. Juvenile coho outmigrate from the river system to the ocean beginning in mid-April and continuing to mid-July (Williams et al. 1975). The shallow areas of the Duwamish estuary provide important habitat for outmigrating coho smolts. Smaller coho tend to remain in shallow shoreline areas and larger fish move into deeper channel areas of estuaries (Nightingale and Simenstad 2001). Upon entry into saltwater as juveniles, coho salmon in nearshore habitats feed upon marine invertebrates such as copepods, mysids, epibenthic amphipods, and crab larvae. As they grow, coho become more piscivorous and prey upon chum and pink salmon as well as forage fish (e.g., sand lance, surf smelt, and anchovy) and crab larvae.

There have been substantial releases of hatchery-origin coho within this area, with regular fingerling/fry plants from the mid-1970s to the present (WDFW et al. 1994).

Dolly varden/Bull trout: Information on the presence, abundance, distribution, and life history of dolly varden/bull trout in the Green River basin is extremely limited (WDFW 1998). Eight adult dolly varden/bull trout were captured in the Duwamish estuary in 2000 (Berge and Mavros 2001). Additionally, there was one sighting of an adult bull trout by the Muckleshoot Indian Tribe at the mouth of Newaukum Creek (Berge and Mavros 2001). Bull trout and dolly varden (*S. malma*) are the only char in the family salmonidae that are native to Washington. Until recently, bull trout were classified with dolly varden under one scientific name. In 1991, the American Fisheries Society supported the decision to split them into two distinct species. Information on the distribution and life history of each species is not yet distinct because the species are biologically similar and methods to separate them are new and not widely applied (Bonar et al. 1997). There is no survey protocol currently endorsed by the USFWS for establishing absence of bull trout, so its presence is assumed where there is suitable habitat (USFWS 1999).

2.5.2.2 Marine Fish

Historically, the Duwamish estuary was likely used for juvenile fish of many species for rearing in the extensive tidal marshes and mudflats. Many marine species including surf smelt, Pacific herring, shiner perch, striped sea perch, pile perch, Pacific staghorn sculpin, and starry flounder spawn or bear live young in intertidal areas. Other species found spawning or resident in the estuary and Duwamish delta were likely threespine stickleback, Pacific snakeblenny, Pacific tomcod, English sole, Pacific sand lance, buffalo sculpin, walleye Pollock, roughback sculpin, plainfin midshipman, tubesnout, bay pipefish, bay goby, sturgeon poacher, speckled sanddab, white sturgeon, and rainbow smelt (USACE 2000). More recently, marine fish species found in abundance in the estuary included Pacific sand lance, snake prickleback, starry flounder, Pacific staghorn sculpin, and shiner perch (Warner and Fritz 1995).

2.5.2.3 Wildlife

The lower Green River basin and Duwamish estuary are heavily developed for industrial and residential purposes. The remaining riparian, wetland, and estuarine habitats are used by a variety of birds and small mammals. The remaining marsh habitats provide exceptional areas for wildlife because of their high biological productivity (USACE 2000). Eighty-four bird species have been observed in the Duwamish River estuary (Tanner 1991). Specifically, Kellogg Island provides important nesting habitat for birds. Nests observed during surveys conducted in the late 1970s included American goldfinch, California quail, Canada goose, gadwall, killdeer, northern oriole, red-winged blackbird, song sparrow, and spotted sandpiper (Canning et al. 1979). Mammal usage of the Duwamish estuary has been limited because the site is surrounded by industrial development and roads. Despite these limitations, nine mammal species have been observed in the Duwamish River estuary (Tanner 1991). Aquatic species include the harbor seal, killer whale, Steller sea lion, muskrat, and river otter, while terrestrial species include the Norway rat, raccoon, snowshoe hare, muskrats, and Townsend vole.

Of the wildlife documented in the Duwamish estuary and lower Green River, only Steller sea lions are listed as threatened by NMFS. Other wildlife species that are listed as threatened by

USFWS that have not been documented in the Study Area, but may be present, include bald eagles and marbled murrelets. More specific information about each of these threatened species is given below.

<u>*Steller sea lions:*</u> Steller sea lions typically remain offshore or haul out in unpopulated areas. Breeding occurs along the North Pacific Rim from Ano Nuevo Island in central California to the Kuril Islands north of Japan, with the greatest concentration of breeding areas in the Gulf of Alaska and Aleutian Islands. This species tends to avoid urban areas, and although occasionally sighted in Puget Sound, the closest regular haulout spot for steller sea lions is the Race Rocks on the Strait of Juan de Fuca (Norberg 1999).

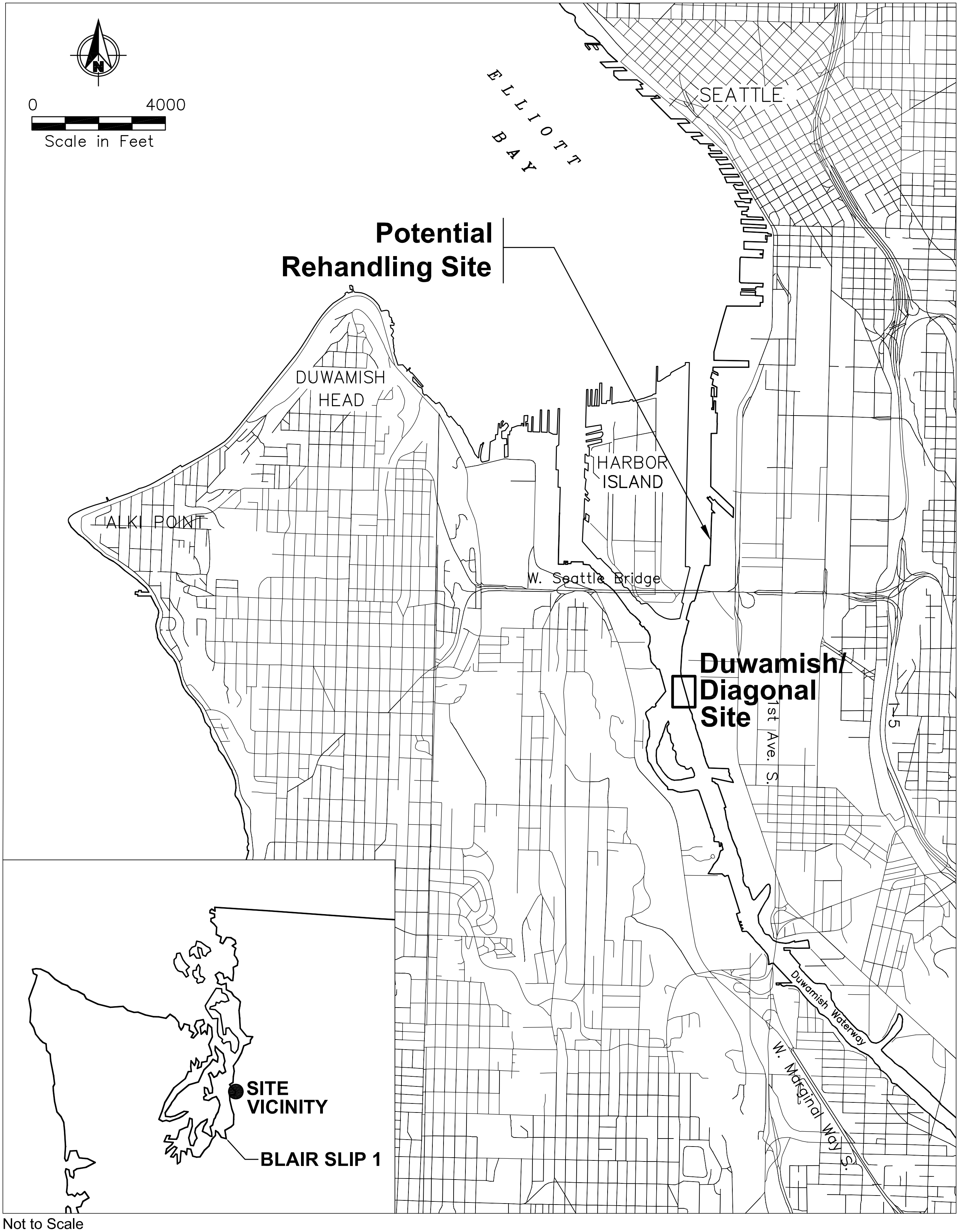
<u>*Bald eagles*</u>: Bald eagles are found only in North America and range over much of the continent, from the northern reaches of Alaska and Canada to northern Mexico. Bald eagles migrate to wintering ranges in Washington in late October and are most commonly found along lakes, rivers, marshes, or other wetland areas west of the Cascade Range (USACE 2000). The limiting factors of bald eagle breeding habitat are nest sites, perch trees, and available prey (USACE 2000). Bald eagles nest primarily in unevenly aged, multi-storied stands with old-growth components (Anthony et al. 1982). In addition to foraging and perching habitats required during breeding, wintering eagles use communal night roosts that are in old-growth coniferous forest near foraging habitat (Stalmaster 1987). Due to the industrial nature of the Duwamish estuary and the bald eagle habitat requirements, eagles are not expected to inhabit the area.

<u>*Marbled murrelets*</u>: Murrelets live near shallow marine waters and, in Washington, nest in mature and old-growth trees (USACE 2000). These birds do not construct nests, but use existing platforms in larger trees. Platforms generally consist of large lateral branches (greater than 4 inches diameter) that are usually moss or lichen covered (USFWS 1997). Nest stand characteristics include a second story of the forest canopy that reaches the height of the nest limb, providing a protective cover over the nest site (USACE 2000). Similar to bald eagles, marbled murrelets are not expected in the project area given the industrial nature of the estuary.

2.5.3 Beneficial Uses

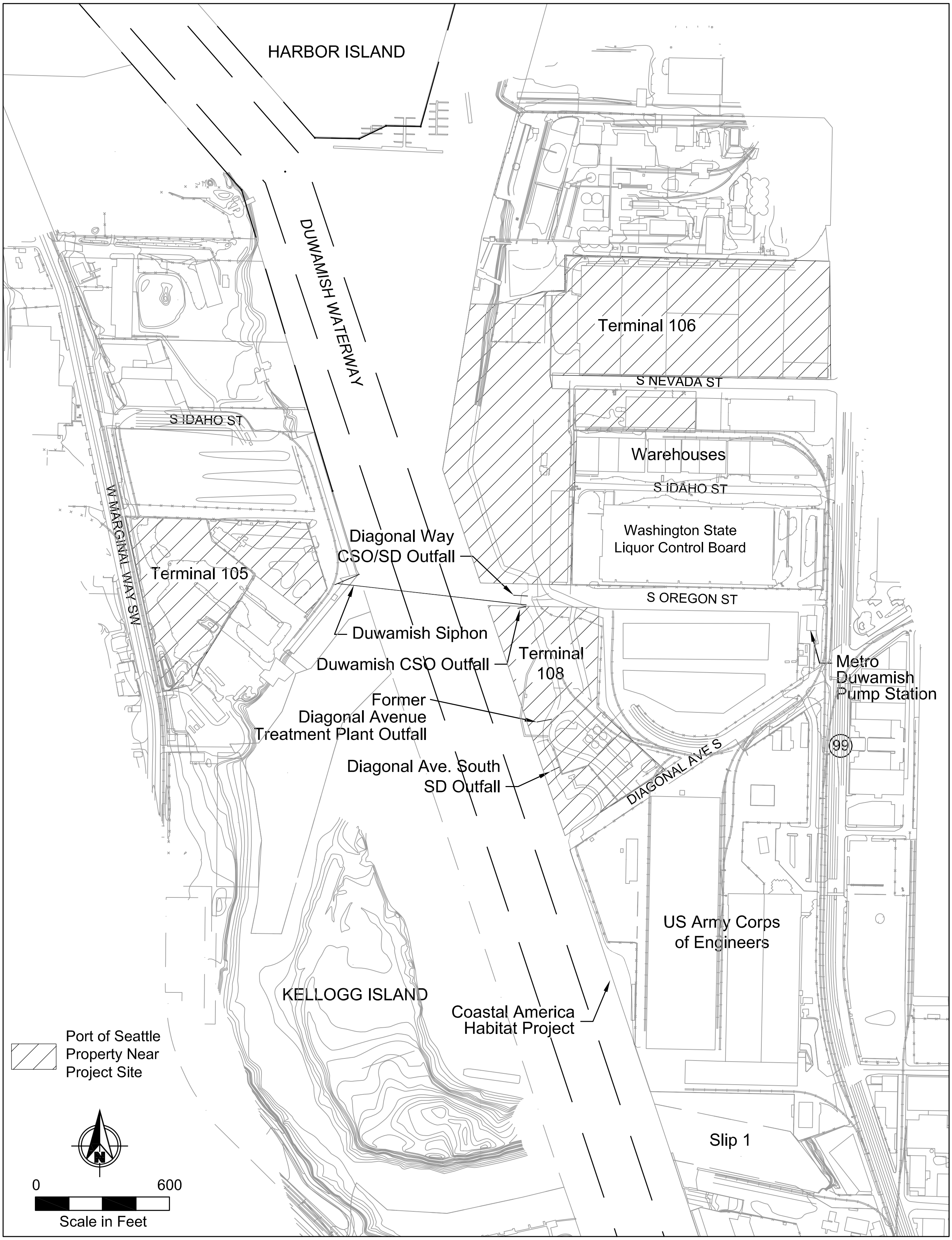
Salmonids are considered the most commercially and recreationally important fish species using the Duwamish River. Species include chinook, coho, and chum salmon, steelhead and sea-run cutthroat trout, and Dolly Varden char (Parametrix 1980).

The Duwamish River estuary is within the usual and accustomed fishing ground of the Muckleshoot Tribe, which harvests almost exclusively non-resident fish such as salmon (EBDRP 1994b). Tribal fishing occurs with river skiff gill nets (PTI 1993). In addition to the tribal fishery, the Green and Duwamish Rivers sustain a major sport fishery for steelhead and are also popular for salmon (Grette and Salo 1986). The Muckleshoot Tribe and Washington State Department of Fisheries operate hatcheries located on tributaries to the Green River. The Muckleshoot hatchery produces chinook salmon, chum salmon, and steelhead trout. The state hatchery has primarily produced coho and fall chinook salmon (Grette and Salo 1986).



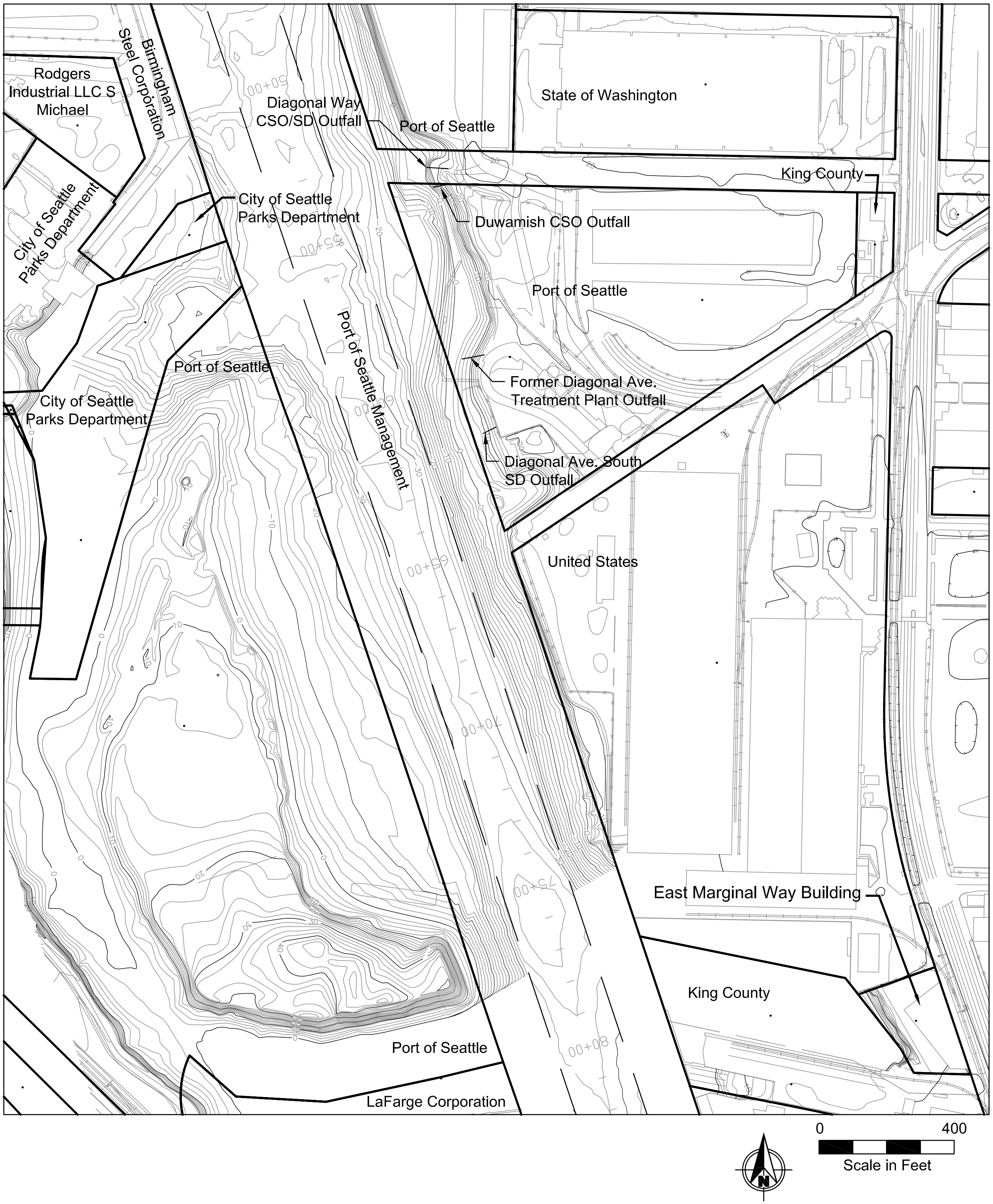
EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 2-1
	Duwamish/Diagonal Vicinity Map	

Sep 08, 2005 2:23pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-28.dwg Fig 2-1



K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-54.dwg Fig 2-2
Sep 28, 2005 2:31pm cdavidson

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 2-2
	Duwamish/Diagonal Area Map	



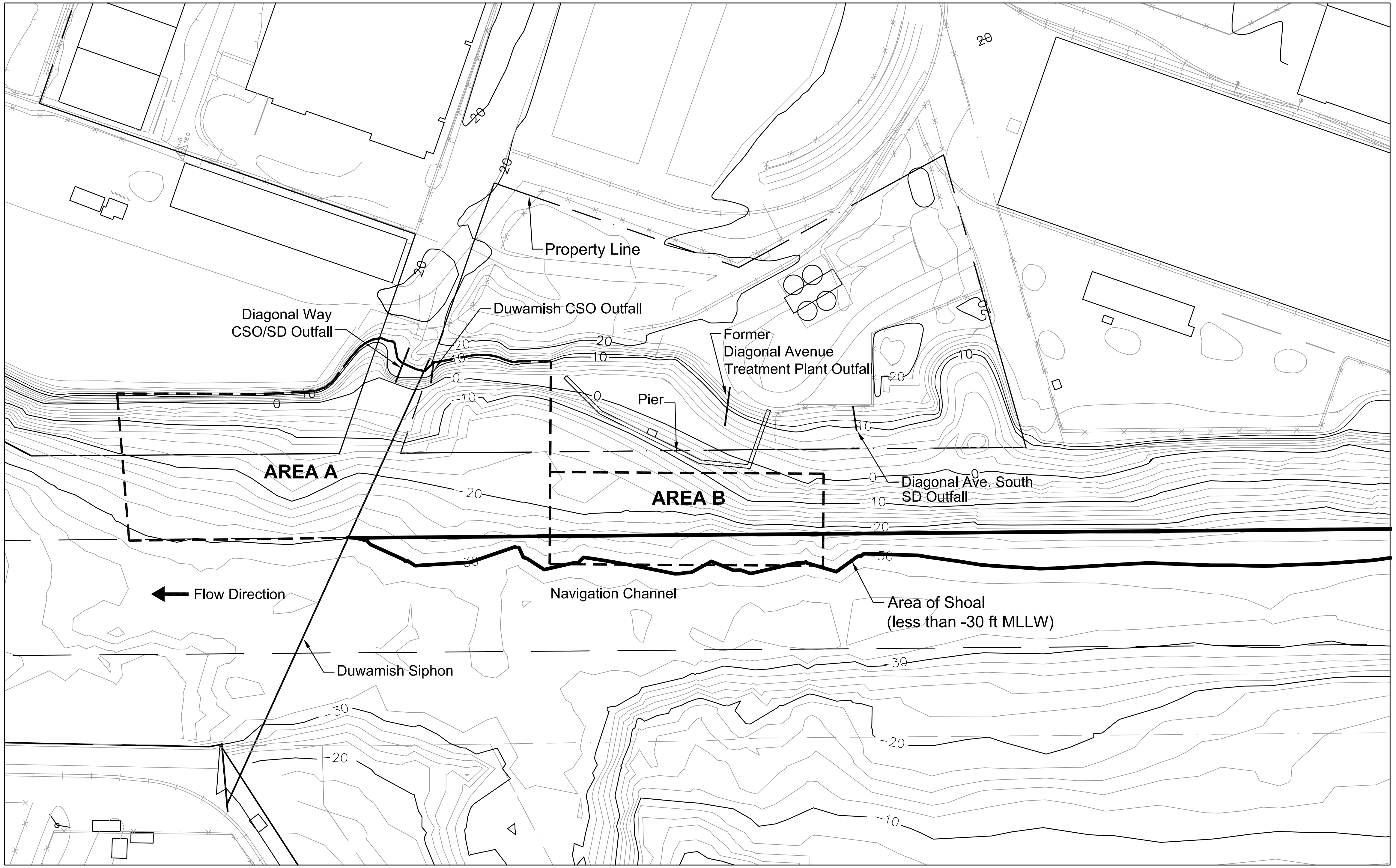
Sep 28, 2005 2:57pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-55.dwg Fig 2-3

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Property Ownership Map

Figure 2-3



0 200
Scale in Feet

—10— Bathymetry Elevation Contours in Feet
(2-Foot Interval)

Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from USACE 1997 survey referenced to MLLW (NOS).

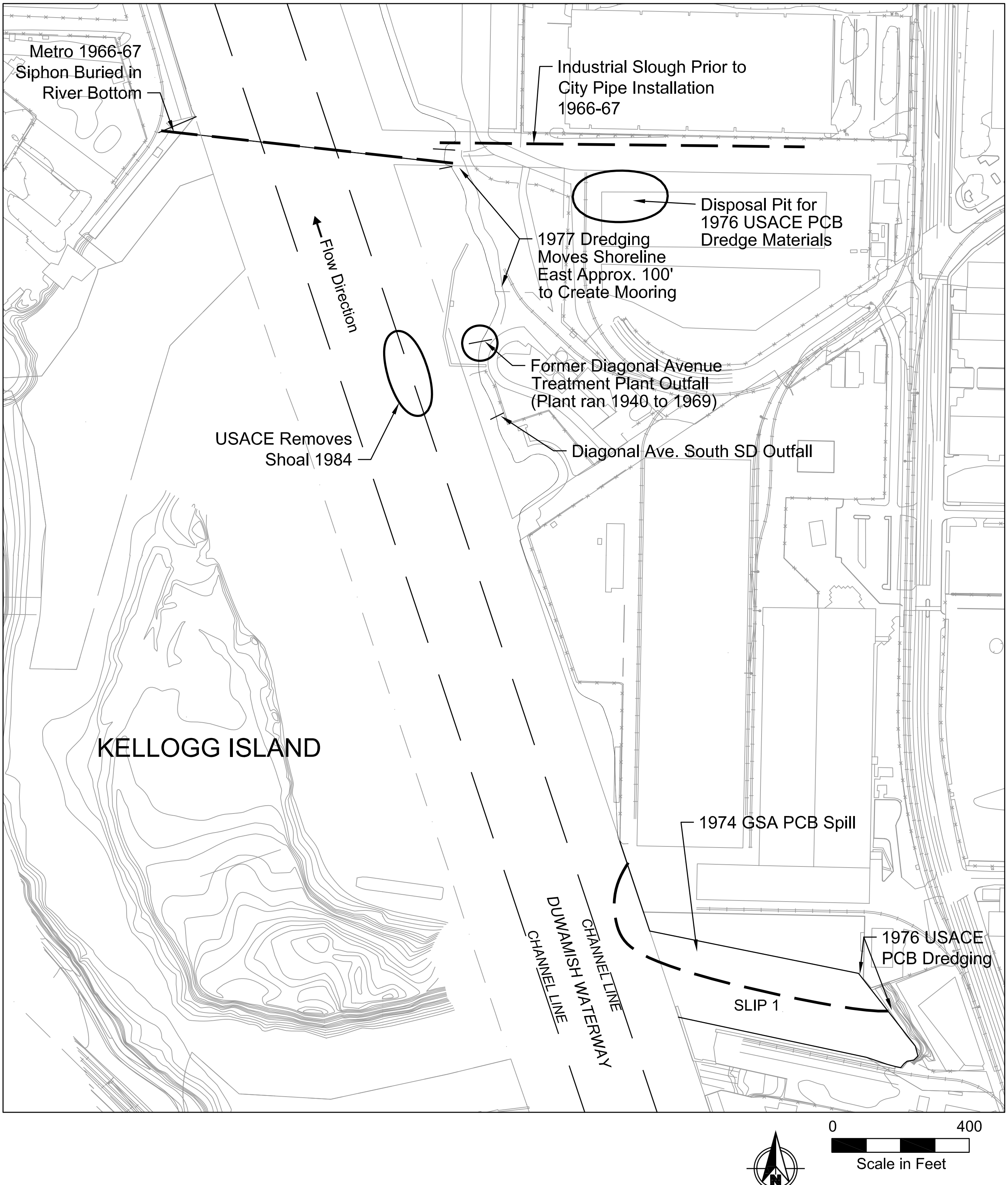
EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Shoreline Features and Bathymetry

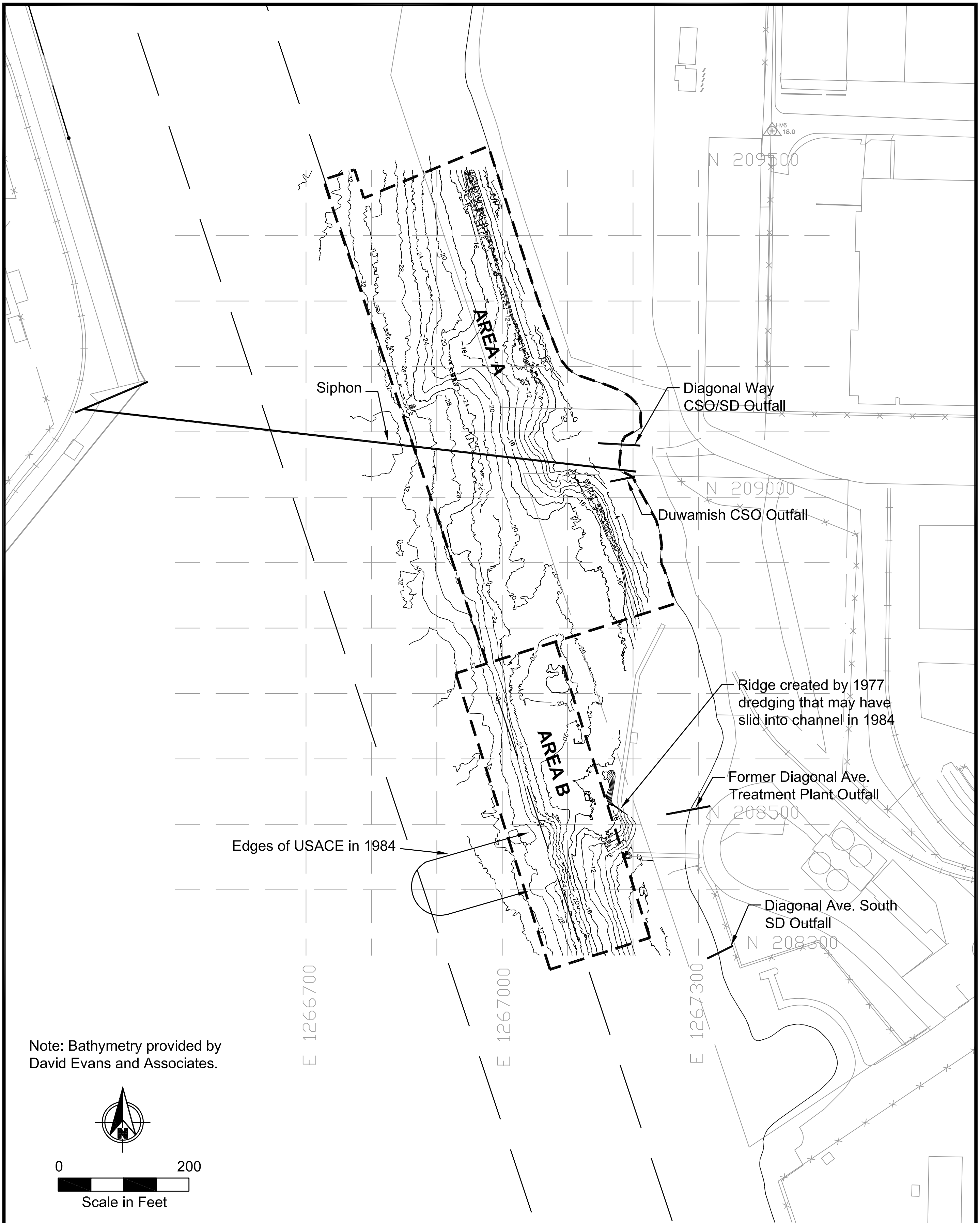
Figure 2-4

Sep 28, 2005 2:58pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-56.dwg Fig 2-4



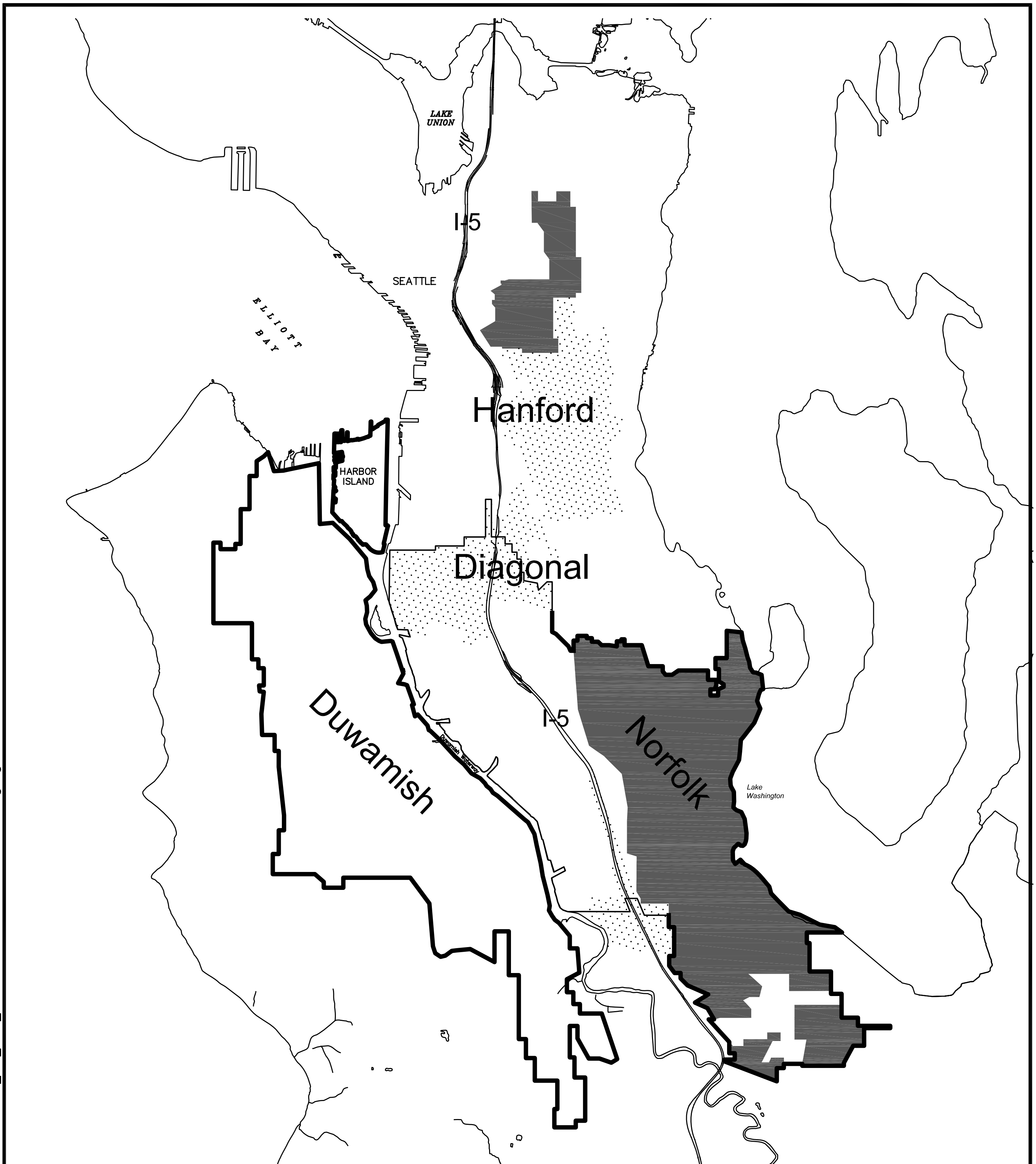
Sep 28, 2005 3:00pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-57.dwg Fig 2-5

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Duwamish/Diagonal Historic Activities	Figure 2-5



Sep 29, 2005 9:40am cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-29.dwg FIG 2-6

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Duwamish/Diagonal 1994 Bathymetry	Figure 2-6



Potential CSO Basin

Storm Drain Basin

Duwamish Pump Site Tributary Area

Source: Duwamish/Diagonal Cleanup Study Workplan, King County Department of Metropolitan Services, August 1994.

Note: In 1997 more detailed drainage maps were used to calculate the total annual storm water flow volume from the Diagonal/Hanford basin. Updated GIS maps should be obtained from either King County or the City of Seattle to insure accuracy in future decisions.

0 8000

Scale in Feet

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Duwamish/Diagonal Drainage Basin Map	Figure 2-7

Sep 20, 2005 12:59pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-58.dwg Fig 2-7

3.0 SOURCE CONTROL EVALUATION

3.1 COMBINED SEWER SYSTEM OVERVIEW

From the early 1900s to the mid-1940s or later, combined sewers were built to collect both sanitary sewage and stormwater in the various drainage basins. These combined sewers have been adequate for conveying dry-weather flows, but are inadequate to handle flows from heavy rainstorms. When flow exceeds the pipe and pumping capacity, the excess flow discharges directly into the receiving waters as CSO at overflow structures.

In the late 1950s, Metro (now KCDNR) was established to develop a regional approach to the conveyance and treatment of sanitary sewage from the Seattle area. The City transferred parts of the combined sewer system in its southern service area to Metro. KCDNR provides conveyance and treatment services for the sewer systems associated with the Duwamish outfall and the City maintains sewer collection systems connected to the Diagonal outfall. Since the 1960s, KCDNR and the City have been constructing projects (including CSO control projects) in the southern service area to improve water quality.

KCDNR oversees an extensive system of conveyance pipelines, regulator stations, and other wastewater facilities (KCDMS 1995). KCDNR's pipelines consist of force mains, trunk sewers, and interceptors. KCDNR trunk sewers pick up flows from the small collection pipelines and convey them to large-diameter interceptors that serve as the conduits for transferring flow to the treatment facilities. After treatment, treated effluent is discharged through outfall pipes to Puget Sound.

CSOs serve as safety valves for the sewer system. In combined sewer systems, the trunk sewers and interceptors have fixed capacities while wastewater flows vary with precipitation. During periods of intense or prolonged precipitation, wastewater flows may exceed the capacity of the sewer pipes to convey wastewater to the treatment plant. To prevent damage to the treatment plant and the backup of wastewater into homes and businesses, the lines are designed to overflow into receiving waters. The control point for overflows occurs at regulator stations.

Regulator stations were constructed by Metro in the early 1970s to control CSOs. They maximize the storage potential available in the large-diameter trunk sewers by shutting off flow to the interceptors during conditions of high storm flows. As a result, wastewater is forced to back up in the trunk sewers. When a trunk sewer reaches its specified storage capacity, an overflow gate is opened and the trunk sewer flow is released through an outfall structure as a CSO.

Metro instituted a formal CSO control program in 1979 under the impetus of the Federal Water Pollution Control Act Amendments of 1972 (KCDMS 1995). In 1987, Chapter 173-245 WAC went into effect under the administration of the Washington Department of Ecology (Ecology), requiring reductions in CSO volumes to an average of one untreated discharge per year at each outfall. Chapter 173-245 WAC also requires CSO plans specifying the means of complying with the regulation. KCDNR and Ecology developed an interim goal of achieving an overall reduction of 75 percent in CSO volume throughout the KCDNR jurisdiction by the end of the year 2005. The *1988 Combined Sewer Overflow Control Plan* (Metro 1988) was developed to implement these CSO reduction goals. The *Combined Sewer Overflow Control Plan 1995* and *2000 Update Plans* (KCDMS 1995, KCDNR 2000) describe the current status and revised future plans. The City has achieved the required level of CSO control in the Duwamish watershed (City of Seattle 1996).

Before Ecology and EPA would approve expanding the cleanup area at the Duwamish/Diagonal site, they requested more information about source control activities to reduce potential recontamination. As a result, King County provided the *Source Control Summary Document* in May 2002 (**Appendix S**).

3.2 POTENTIAL CONTAMINANT SOURCES

Potential contaminant sources in the Study Area include stormwater and CSO outfalls, surfacewater runoff, and groundwater inflow. Active outfalls include the Diagonal Way CSO/SD, and Diagonal Avenue South outfalls. The former Diagonal Avenue treatment plant outfall represents an historical discharge source as does the Duwamish CSO, which has not had an overflow for over 10 years. In addition, industrial discharges, dumping, and dredging operations may have contributed contaminants to the Study Area.

3.2.1 Diagonal Stormwater and CSO Outfall

The Diagonal Way CSO/SD outfall receives primarily stormwater and minor CSO flows from both the Diagonal (1,012 acres) and Hanford (1,573 acres) drainage basins. It is the City's largest stormwater outfall, handling runoff from approximately 2,585 acres of residential, commercial, and industrial properties and approximately seven miles of I-5. The drainage basin contains hundreds of commercial and industrial businesses. Potential sources of phthalate contamination to the Diagonal Way CSO/SD outfall identified by the Elliott Bay Action Program (Tetra Tech 1988) include the former operations of Janco-United (which distributed degreasing compounds containing phthalates and chlorinated benzenes; see **Appendix G**), a machine shop, a tank cleaning service, a utility storage area, and the former Sixth Avenue South landfill. The landfill operated for 30 years prior to about 1955 and received dredged sediments from the lower Duwamish River (Duwamish Waterway). The landfill was added to Ecology's No Further Action list November 12, 1997. A 1984 EPA investigation of Janco-United found high concentrations of phthalates, chlorinated benzenes, and volatile organic compounds in soils and drains at the facility. The investigation resulted in criminal charges and fines (EBDRP 1994b), but no cleanup was conducted by EPA (Schmidt 2002). Ecology considers the problem to have been a water quality violation, and the site is not considered a contaminated site by Ecology (Cargill 2002).

Sediment samples were collected from the Diagonal Way CSO/SD outfall in 1985 during the Elliott Bay Action Program. Two sediment samples were collected in the Diagonal storm drainpipe, (see **Appendix B**, Table 3-1 – Diagonal Way and Diagonal Avenue South Storm Drain Samples Compared to Standards*)*. The first sample was at a manhole (Diag MH1) and the second was located approximately 25 feet upstream of the manhole (Diag MHU). These historic data for both samples were normalized for total organic carbon (TOC) and compared to the state sediment standards adopted in 1991. At Station Diag MH1, there were 21 detected parameters that exceeded Washington Sediment Quality Standards (SQS), and eight of these also exceeded the Cleanup Screening Level (CSL). The eight compounds exceeding their CSLs were total low molecular weight polycyclic aromatic hydrocarbons (LPAHs), indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, phenol, and 4-methylphenol. At Station Diag MHU there were seven detected parameters that exceeded their SQSs, with five of these exceeding their CSLs. The five compounds exceeding the CSLs were mercury, 1,4-dichlorobenzene, dibenzofuran, total PCBs, and 4-methylphenol.

The City DWU sampled sediment from the Diagonal storm drain system in 1988, 1989, and 1994. The 1994 sampling results are presented in **Appendix G, Figure 5**. Results for the four sediment samples indicate no SQS exceedances for metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc). Concentrations of bis (2-ethylhexyl) phthalate exceed the second lowest apparent effects threshold (2LAET; comparable to CSL criteria for low TOC samples) dry weight (DW) criteria of 1.9 mg/kg (1,900 μg/kg) in two of the four samples, and the other two samples exceeded the lowest apparent effects threshold (LAET; comparable to the SQS criteria for low TOC samples) DW value of 1.3 mg/kg (1,300 μg/kg).

An oily discharge has been observed from the Diagonal storm drain and is also present in the muddy delta below the discharge. The oil sheen is considered to be recent because it was first reported as a problem in 1997 and continues to be seen intermittently. The City DWU has attempted unsuccessfully to trace this oil discharge back to its source (**Appendix D;** page titled Summary of the City's investigation of oil sheen at the Diagonal Outfall, Feb. 7, 1997). The oil sheen has been reported several times between 1998 and 2001. The City continues to try to locate the source of the oil sheen, but has not yet succeeded. In the meantime, the City installed an oil containment boom and an oil absorption boom off the end of the Diagonal SD discharge structure. No effort has been made to remove the oily sediment from in front of the Diagonal SD outfall, however, this area will be included as part of the proposed Duwamish/Diagonal Cleanup project.

The *Source Control Summary Document* (**Appendix S**) includes a discussion of chemistry data from new sediment samples from pipes in the Diagonal Way CSO/SD basin plus the chemical quality of CSO water samples (see section 7 of **Appendix S**). During the first two moths of 2002, the City DWU collected 11 new sediment samples from the Diagonal Way CSO/SD basin to characterize sediment for pipe cleaning that was conducted during the summer of 2002 and 2003. CSOs discharging to the Duwamish River were sampled in 1996 and 1997 and were reported in the *King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (KCDNR 1999).

3.2.2 Duwamish CSO Outfall

The Duwamish CSO outfall is a relief point for the Duwamish Pump Station and the Duwamish Siphon. The outfall is located at the east bank of the Duwamish River just south of the Duwamish Siphon Aftbay next to the LaFarge Corporation Cement Company. Combined sewage and stormwater (combined wastewater) from the East Marginal Way Pump Station and combined wastewater originating in subbasins north of the East Marginal Way Pump Station service area and south of the Hanford Trunk (a total area of 2,205 acres) are directed to the Duwamish Pump Station. Combined wastewater from the Delridge Trunk Sewer and the Chelan Avenue Regulator Station flowing through the Duwamish Siphon is also directed to the

Duwamish Pump Station. The Duwamish CSO outfall protects the Duwamish Pump Station from flooding. A combined sewer overflow event would be triggered only if the level in the pump station wet well exceeded a maximum set point. The Duwamish CSO outfall has not discharged since 1989 (details of this discharge are unknown).

The Duwamish Pump Station has a peak flow of 63 MGD and a maximum pumping capacity of 100 MGD (three pumping units). An engine generator unit provides emergency power for the station. Also, under normal dry weather conditions (23 MGD), the station has two hours of storage time from shutdown to overflow. Finally, the Duwamish Pump Station is equipped with sensors for key operational conditions. Alarm signals are connected to telemetry sending alarm signals to West Division Main Control for continuous monitoring. Therefore, during normal conditions, it is unlikely that the pump station wet well will exceed a maximum set point because the station has been designed with enough reliability that overflow into the Duwamish River will not occur. If, however, an emergency discharge due to system demands up- or downstream of the Duwamish Pump Station were required at the Duwamish CSO, the chemical concentration of the discharge would likely be similar to the concentration that is found regularly in either sewage or CSO samples routinely taken from the sewer collection system and treatment plants.

Industries located in the Duwamish service area are potential dischargers of contaminants to the collection system. Seven industries permitted to discharge to the Duwamish sanitary sewer system are located on the west side of the Duwamish Waterway. The permitted industries include a metal recycler, three metal finishers, a barrel-rinsing operation, stormwater discharge from a petroleum tank farm (ARCO on Harbor Island), and a stormwater and combined wood-preserving wastewater discharger (EBDRP 1994b). Seafab Metal Corporation on Harbor Island also has a discharge authorization to route some stormwater (from roof drains) to the sanitary sewer (EBDRP 1994b). This discharge was authorized to prevent direct discharge of contaminated stormwater to the waterway. In addition to permitted discharges and minor discharge authorizations, other minor discharges may result from commercial discharges (e.g., photo developers and gas stations; EBDRP 1994b).

No overflow conditions were observed for the pump station wet well during the period monitored from 1989 to the present. Consequently, discharges from the Duwamish outfall have not been sampled. Regular sampling of influent to the Duwamish Pump Station has been performed by KCDNR's Industrial Waste Section, but not during storm periods.

3.2.3 Diagonal Avenue South Storm Drain

The Diagonal Avenue South SD discharges runoff from a relatively small 12-acre basin adjacent to the Duwamish River and approximately 1,000 feet upstream of the Study Area. The basin is paved and has been used for storage by the surrounding properties (Tetra Tech 1988). A sediment sample (DiagS) was collected from the Diagonal Avenue South SD during the Elliott Bay Action Program. The data for this historic sample were normalized for TOC and compared to Washington SQS (see **Appendix B**'s Table 3-1—Diagonal Way and Diagonal Avenue South Storm Drain Samples Compared to Standards). At Station DiagS, four detected analytes exceeded SQS values, and one exceeded a CSL value (chromium). The total contaminant contribution from the Diagonal Avenue South outfall is expected to be minor for the following reasons:

1. The Diagonal Avenue South drainage basin is less than 0.5 percent (12 acres out of 2,585 acres) of the size of the Diagonal/Hanford drainage basins.
2. The sediment samples taken near the Diagonal Avenue South outfall do not exceed the SMS standards for most chemicals, except phthalates.
3. Part of the 12-acre basin formerly occupied by LaFarge Cement manufacturers is now vacant, and property to the north of this vacant area has been converted by the Port of Seattle to a container storage facility.
4. In an effort to minimize pollutant discharges to the storm system, the City of Seattle is scheduled to perform additional business inspections in all drainage areas tributary to the Duwamish/Diagonal site.

3.2.4 Former City Treatment Plant Outfall

The former Diagonal Avenue treatment plant was located near the river about 150 m to the south (upstream) of the Diagonal Way CSO/SD outfall. The treatment plant was built by the City and began operation in 1940. Plant capacity was 7 to 8 MGD of primary treatment with only a two-hour wastewater retention time (EBDRP 1994b). Metro was formed in 1958 to improve sewage treatment in the Seattle area, and took over operation of the plant in 1962. This plant was operational until 1969 when the final stage of the Elliott Bay Interceptor pipeline was completed and flows were diverted to the West Point treatment plant. The Diagonal Avenue treatment plant treated wastewater from Seattle's primary industrial core and was considered to be one of the most overloaded plants in the Seattle system (EBDRP 1994b). Flow to the plant was limited by an upstream regulator that provided a bypass directly to the Duwamish River south of Slip 1 (Brown and Caldwell 1958). Due to the combined storm and sewer system, the plant frequently diverted untreated sewage into the Duwamish River during rain events (EBDRP 1994b). Treatment plant structures were removed in the mid-1970s, except for two below-ground clarifiers that were filled (AGI 1992). The sludge in the drying beds was covered with fill (AGI 1992), probably excavated from the nearshore area when a berthing area was dredged in 1977.

A large portion of the contaminated sediment that may have been associated with the old treatment plant outfall appears to have been removed in 1977 when Chiyoda Corporation dredged a nearshore berthing area on the north side (downstream) of the old outfall. Chiyoda Corporation acquired the former treatment plant site in the mid-1970s. Little is known about Chiyoda Corporation's operations, except that it was a chemical company that wanted to develop a shore-based loading dock. They dredged the inshore area, but were unsuccessful at obtaining permits for the shore-based dock. Later, a mooring dock of piling clusters was built offshore.

In 1976, PCB-contaminated dredge spoils from a 1974 transformer fluid spill in Slip 1 (containing Aroclor 1242) were disposed on the Chiyoda property by the USACE (**Figure 2-5**; Sweet, Edwards & Associates and Harper-Owes 1985; AGI 1992). Two lagoons were excavated along the northern edge of the property in the former treatment plant sludge bed areas for treatment of approximately 10 million gallons of PCB-contaminated sediment dredged from near Slip 1 (C-3, **Appendix C**). PCB-contaminated sediment was deposited primarily in the first receiving lagoon located closet to the river. Water pumped from the disposal lagoons was treated by particulate, sand, and charcoal filters prior to discharge to the Duwamish Waterway

(AGI 1992). The PCB disposal pits were eventually backfilled with material from the excavation and additional sediment that Chiyoda dredged from the shoreline to improve berthing (AGI 1992).

The Port of Seattle acquired the Chiyoda property in 1980. The Port later sold part of the property to Chevron, retaining the portion along the river. Soil contaminated with petroleum hydrocarbons was stockpiled in the vicinity of the former disposal lagoons (AGI 1992). This soil was treated to meet the State of Washington total petroleum hydrocarbon (TPH) cleanup level of 200 mg/kg. The Port leased the southern part of the site to Lafarge Cement Company, which occupied the site from 1989-1998 and loaded cement barges at the mooring pile dock. This site is currently the Port of Seattle's Terminal 108 expansion area and is used for container storage.

3.2.5 Other Potential Sources

In 1974, a major PCB spill occurred near the Study Area when a transformer cracked while being loaded onto a barge in Slip 1. The location of Slip 1 is about 1,000 m (3,300 feet) upstream of the Duwamish/Diagonal outfalls. Approximately 250 gallons of near-pure PCB (Aroclor 1242) were spilled into the Duwamish River. The majority of this material was recovered during the dredging operations that followed the spill. PCB concentrations were monitored during the cleanup operation and mean concentrations were within the normal observed ranges. A report prepared for the USACE in 1978 concludes that, based on these monitoring results, the spill did not contribute a significant PCB loading to the lower Duwamish (USACE 1978). However, sediment samples taken by EPA in 1998 showed measurable levels of PCBs remain in the sediment in the dredged channel both upstream and downstream of Slip 1 (Weston 1999).

The Duwamish River is frequently dredged for navigational purposes (EBDRP 1994b). There is a potential for dredging operations to resuspend sediments, which could result in transport of contaminants to other areas. There is also a potential for contaminated sediments located downstream (e.g., at Harbor Island), to be transported upriver to the Study Area due to tidal action and movement of the salt wedge.

3.2.6 Surface Water Runoff

In the past, contaminants may have been carried to the vicinity of the Duwamish/Diagonal outfalls in surface water runoff from Terminal 106 and the former Chiyoda/Chevron property, but no information was found that documents contaminants in surface runoff from these areas. Current drainage patterns are unknown. Terminal 106 has a small surface drain (discussed in **Section 2.4.2**) that historically discharged along shore on the north side (downstream) of the Diagonal outfall, but more recently was connected to the Diagonal outfall; no drainage pipes were observed at Terminal 108. The presence of halogenated organic compounds and petroleum products was confirmed in surface water from the Coastal trailer repair site formerly located at Terminal 106 (EBDRP 1994b). A large part of the former Diagonal Avenue Treatment Plant site has been paved over with asphalt for container storage, reducing the possibility that surface water will come in contact with contaminated sediments buried on the site.

Water column sampling for toxicants in the Duwamish River was performed by Metro in 1985. Copper, nickel, and lead concentrations measured in Duwamish River surface water samples collected downstream of the Duwamish/Diagonal outfalls, near the West Seattle Bridge and Harbor Island in 1985, exceeded the marine chronic Ambient Water Quality Criteria (AWQC) (Metro 1987). As part of the *Duwamish River/Elliott Bay Water Quality Assessment*, water samples were collected both upstream and downstream of the Duwamish/Diagonal outfalls between November 1996 and May 1997. However, no samples were collected directly offshore of the Duwamish/Diagonal outfalls. These samples were analyzed for metals, organics, nutrients, and microbiological parameters and a risk assessment was performed. There were no unacceptable risks attributed to chemical levels in the water column (KCDNR 1999).

3.2.7 Groundwater

Several potential sources of groundwater contamination exist. As discussed in **Section 3.2.4**, sludge and PCB-contaminated dredge spoils are buried in the vicinity of the former Diagonal Avenue treatment plant. PCBs and metals are typically identified as contaminants of concern at former sludge bed locations (EBDRP 1994b). Additionally, a groundwater study identified Ash Grove Cement, Seattle City Light Substation, ChemPro, Liquid Carbonic Corporation, and several refuse dumps, mounds, and waste pits as potential sources of groundwater contamination in the Study Area (Sweet, Edwards & Associates and Harper Owes 1985).

Groundwater samples were collected from 14 wells at the Chiyoda/Chevron property located upstream of the Duwamish/Diagonal outfalls during October 1991 (dry season conditions) and January 1992 (wet season conditions) (AGI 1992). Groundwater is expected to flow to the Duwamish Waterway, but groundwater discharge rates and discharge points were not determined (AGI 1992). Hydraulic conductivity was not determined, but soil classification and observations during well construction suggest that the water-bearing portion of the fill has low permeability. Depth to groundwater ranges from 2 to 4 m at the property. PCBs were not detected in groundwater samples (detection limit 0.1 µg/l)**,** except in one duplicate sample. Aroclor 1248 was identified in this sample at a concentration of 0.3 µg/l. Because PCBs are not very mobile in groundwater and PCBs were generally undetected in groundwater samples, PCBs in groundwater are not expected to pose a risk to aquatic receptors in the waterway.

Polycyclic aromatic hydrocarbons (PAHs) were detected in Chiyoda/Chevron property groundwater samples. Total PAH concentrations measured in groundwater samples ranged from "not detected" in the southern portion of the property to 7.6 µg/l in the center of the property. PAH concentrations measured in groundwater samples exceed state guidelines (Model Toxics Control Act [MTCA] Method A). Diesel fuel and gasoline were measured in nine of 14 wells at concentrations ranging from 30 to 490 µg/l (AGI 1992). Few AWQC are available for PAHs for comparison, but the Lowest Observed Effects Level for total PAHs is 300 µg/l. Because total PAH concentrations were not measured in groundwater samples at levels exceeding the Lowest Observed Effects Level, it is unlikely that PAHs pose a risk to aquatic receptors in the waterway.

The maximum concentrations of cadmium (38 µg/l), copper (200 µg/l)**,** lead (260 µg/l), mercury (0.3 µg/l), nickel (380 µg/l)**,** and zinc (6,200 µg/l) measured in groundwater samples from the Chiyoda/Chevron property exceed ten times the marine chronic AWQC (AGI 1992). To be below AWQC, maximum concentrations of lead, nickel, and zinc would require dilution of over

45-fold before discharge to the waterway. It was not indicated whether the samples were filtered or unfiltered prior to analysis. Of the metals measured in groundwater at significant concentrations, only mercury has been detected in the preliminary sediment samples collected near the Duwamish/Diagonal outfalls at concentrations exceeding the Washington SMS.

3.3 STRUCTURAL IMPROVEMENTS AND WATERSHED SOURCE CONTROLS

If sediment in the vicinity of the Duwamish/Diagonal outfalls is remediated, adequate control of combined sewer overflows, storm drains, and industrial sources will also be necessary to prevent sediment recontamination. Structural improvements, as well as source controls, have been implemented for the Duwamish and Diagonal sewer and stormwater systems and are described below.

3.3.1 Duwamish CSO Outfall

Due to the configuration of the Duwamish outfall as an emergency overflow, CSO discharges are highly unlikely (EBDRP 1994b). No overflows have occurred since 1989, and none are anticipated in the future except under emergency conditions. Formal source control projects (other than periodic investigations and trouble call response by KCDNR's Industrial Waste and Water Resources staff) have not been conducted in the service areas tributary to the siphon (EBDRP 1994b). However, KCDNR's Local Hazardous Waste Management Program provides technical advice on proper industrial waste disposal methods to the Environmental Coalition of South Seattle, which provides information to local industries.

3.3.2 Diagonal Way CSO/SD Outfall

The Diagonal Way CSO/SD outfall receives flows from both the Diagonal and the Hanford drainage basins. There are a few local CSO points that can discharge into the stormwater system in the Diagonal basin, but these have been controlled by separation and storage to less than one overflow event per year. Part of the CSO control for the Hanford basin was the installation of a pipe within the Hanford Tunnel that transports sewage to the EBI. Stormwater is conveyed separately to the Diagonal outfall. This separation project was completed in 1987 and was thought to have totally eliminated KCDNR's Hanford 1 CSO, which previously discharged over 300 MGY at the Diagonal Way CSO/SD outfall. However, recent information has revealed that the Hanford 1 CSO is not totally controlled, but is now estimated to discharge about 20 times per year with a total annual average volume of about 65 MGY (Swarner personal communication 1999). Further work to control Hanford 1 is scheduled for early 2020, which is similar for all King County discharges to the Duwamish River.

Source control within the Diagonal and Hanford drainage basins is being implemented. The City DWU has completed a preliminary review of businesses in the basins to identify those likely to introduce pollutants or sediments into the stormwater system. Based on standard industrial classification codes, the City identified approximately 1,000 businesses that could potentially conduct work outside or store materials outdoors. The majority of these businesses involved manufacturing, scrap yards, transportation, or automotive repair. Of these businesses, it was determined that more than 700 do not conduct outdoor activities that could potentially harm the environment (City of Seattle 1996). The remaining businesses were targeted for source control inspections (**Appendix D**). The objective of these inspections is to control contamination input from upland drainage basins by promoting best management practices, including disposal/storage activities and housekeeping practices, and to increase local awareness of the importance of protecting water quality.

The DWU also responds to reports from the public for inquiry or investigation of water quality problems in storm systems and streams (City of Seattle 1996). A review of DWU records produced only a small number of complaints for these two basins. For the years 1990 to 1994, 12 problems were reported in the Diagonal basin and nine in the Hanford basin (City of Seattle 1996). The majority of these complaints were related to fluid spills from private auto maintenance and illegal dumping of materials, with only one large spill being reported. The DWU has been actively engaged in increasing public awareness through source control inspections and newsletter mailings. Over the past few years several complaints have been raised about an oil sheen that is sometimes present in the discharge plume. In 1999, the City installed an oil containment boom at the Diagonal Way CSO/SD outfall and is continuing efforts to locate the source (**Appendix D**).

The removal of sediment from storm lines has also been identified as a method of reducing contaminant loadings to the Duwamish River. Seattle Engineering's Transportation Department has the responsibility for maintaining storm lines, catch basins, and storm sewer inlets in the City. DWU reviewed maintenance records for storm structures and estimated that there are approximately 1,300 and 1,400 inlets within the Diagonal and Hanford basin boundaries, respectively. Historical maintenance records document yearly checks of inlets for sediment depth, with scheduled pump-outs usually on alternate years. The DWU conducted pipe cleaning in selected areas of the Diagonal basin during the summers of 2002 and 2003.

3.4 RECONTAMINATION MODELING RESULTS

Sediment recontamination modeling was conducted on four separate occasions, using three different methods, in attempts to characterize the likelihood of recontamination of the sediment in the Study Area following cleanup. If the modeling results indicated the potential for recontamination of the sediment by these sources, then additional source control or treatment measures would need to be considered for the Diagonal/Duwamish basin.

The first modeling effort was undertaken in 1996 by KCDNR, using a modification of the SEDCAM model they named METSED. The second modeling effort occurred when this modeling had to be modified in 1997, because new information from the City significantly increased the assumed stormwater discharge for the Diagonal SD from an estimated annual flow of 685 MGY to 1,230 MGY. These assumptions and observations are summarized in Section 3.4.1. The full modeling report, including the update information, is presented in **Appendix H.**

The third modeling effort was conducted by WEST Consultants in 1999, using direct field observations, supplemented by analytical and numerical results, to perform a mass balance between the chemicals observed in the "footprint" and the various sources, including background. Their assumptions and observations are summarized in **Section 3.4.2**. The full modeling report is presented in **Appendix I**.

The fourth modeling activity was conducted by Anchor Environmental, LLC (Anchor) in 2001 using existing models to perform a semi-qualitative screening level analysis to predict the amount of PCB recontamination that would occur from an adjacent PCB hot spot both prior to remediation and during remediation dredging. The model also predicted decreases in PCB values due to natural recovery processes near the discharge and away from the discharge. Results of PCB recontamination and recovery are summarized in **Section 7.3** and the full modeling report is presented in **Appendix P**.

Recontamination modeling results are discussed in three different chapters of this Cleanup Study Report (**Sections 3, 5, and 7**), and this modeling information is consolidated into five pages of the Source Control Summary Document (**Appendix S**). Phthalate and PCB recontamination are discussed in Sections 8 (three pages) and 10 (two pages), respectively, of that document.

3.4.1 METSED Model – KCDNR

Sediment recontamination modeling was conducted by KCDNR to evaluate the likelihood of recontamination of the sediment at the site after sediment cleanup has occurred. Modeling results are included as **Appendix H**. The potential concentration increase of various sediment contaminants in the cleaned area near the discharge was to be modeled.

The model used for the evaluation is based on SEDCAM (Ecology 1991). It was modified by KCDNR staff and renamed METSED. METSED assumes that chemicals discharged to the receiving water (the Duwamish River) are well mixed in a control volume overlying the sediments. Assuming the ambient flow of water in the river, the concentration of chemicals entering the control volume, the CSO/SD discharge flow rate, and concentrations of the same chemicals in the discharge, the model computes the exchange between the water column and the underlying sediment to estimate sediment concentrations. Processes modeled include mass accumulation, constituent decay, and chemical partitioning.

In applying METSED, it was assumed that discharge from the Diagonal outfall would mix into a fraction of the Duwamish River, characterized by a mixing zone width. Particle size distributions and settling velocities were obtained from the USACE *Duwamish Waterways Navigational Improvement Study* (USACE 1981). The average flow in the Duwamish River was assumed to have a constant discharge per unit width. Discharge concentrations were specified using CSO data collected by Metro at a number of area CSO sites. For some chemicals, these average CSO concentrations tended to be higher than average stormwater concentrations collected in the Diagonal drainage basin; therefore, use of the average CSO concentrations in the recontamination model is considered a more conservative analysis.

The conclusion of this modeling effort by KCDNR is that cleaned sediment in the vicinity of the Duwamish/Diagonal outfalls would likely be recontaminated above the SQS by bis (2-ethylhexyl) phthalate and butyl benzyl phthalate. This modeling approach was not totally consistent because it also predicted that two metals would pose a greater recontamination potential than the two phthalates. However, the measured surface sediment concentrations at the site showed that these two metals did not exceed the SMS values as was predicted by the model. This conclusion led to further modeling, using another approach, in an effort to confirm or refute these findings.

3.4.2 Mass Balance Model – WEST Consultants

A basic mass balance modeling approach was selected because it relies on the simplest assumptions and is based primarily on field observations, supplemented by numerical modeling results, to define the relationship between discharges from the SDs and CSOs, and the nearby sediment. This approach was used to determine the discharge load reduction necessary for each constituent to maintain sediment quality compliance in the Duwamish/Diagonal footprint following cleanup. Various approximations and estimates were required to establish input values for the following parameters:

- Average discharge volumes from SDs and CSOs
- Discharge sediment loads
- Discharge constituent concentrations
- Mass of discharged constituents deposited beyond the “footprint”
- Background river loading

Assumptions included:

- Sediment from the SDs and CSOs settle in the same proportion as measured in their respective discharges
- There are no chemical transformations or decay in the sediment
- Background deposition is uniform and known
- The “footprint” is in equilibrium with existing discharges

Once the model was run to “validate” these estimates and assumptions, the model was rerun to solve for SD and CSO constituent concentrations that would be necessary to maintain sediment quality compliance after cleanup. The full modeling report is included as **Appendix I.**

The study area for the model was the Duwamish River in the vicinity of the Diagonal outfall. The chemicals modeled included chrysene, fluoranthene, pyrene, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, and 1,4-dichlorobenzene. Sediment data used in the modeling came from the findings of this *Duwamish/Diagonal Site Assessment* study (**Appendix A**). Data from the KCDNR were used to estimate CSO and SD discharge rates and discharge contaminant concentrations. The background sediment deposition rate, 2.8 cm/yr, was determined from the results of the three-dimensional circulation and sediment transport modeling performed by the KCDNR. When the background of 2.8 cm/yr is subtracted from the rate of sedimentation in the footprint of 3.5 cm/yr, the outfalls were assumed to contribute the difference of 0.7 cm/yr. Background sediment concentrations for each constituent were developed by averaging the measured concentrations at two points beyond the “footprint.”

The results of this modeling effort indicate that chrysene, fluoranthene, pyrene, and 1,4-dichlorobenzene will not exceed the SQS after cleanup (i.e., recontamination is unlikely to occur). For butyl benzyl phthalate however, recontamination is indicated, even if discharge from the SD is completely eliminated. Virtually the same is true for bis (2-ethylhexyl) phthalate. Depending on the background concentration assumed for bis (2-ethylhexyl) phthalate, upwards of 87 percent of the source would have to be eliminated to maintain sediment concentrations below the SQS after cleanup.

The report also identifies important limitations to this method imposed by the available data. Improved knowledge of settling rates near the discharges, chemistry of the discharges, and chemistry of the background sediment would greatly reduce the uncertainties present in the current analysis. However, simulation of the complex physical and chemical processes that create the "footprint" from the various discharges will remain difficult.

3.4.3 Factors Supporting Remediation

Achievement of adequate source control prior to remediation is the ideal project goal. However, there are at least four factors that come into consideration when assessing whether a sediment remediation action should proceed despite high potential for recontamination.

1. What is the feasibility of achieving source control to remove the problem chemical?
2. Is there information that indicates the problem chemical is actually less toxic than predicted by the SMS value?
3. Is the predicted recontamination area small compared to the entire remediation area?
4. Does remediation remove chemicals of greater concern than the chemicals that are predicted to recontaminate the site?

Consideration of these factors that could support moving ahead with the project are discussed further in **Section 5.4**.

4.0 DATA COLLECTION AND RESULTS

4.1 STUDY OBJECTIVES

The overall objective of the data collection effort was to characterize the spatial extent and magnitude of sediment contamination resulting from the discharge of the Duwamish/Diagonal outfalls into the Duwamish River. Chapter 4 discusses the data collection and results of KCDNR work. The 1998 EPA data (Weston 1999) is included in data interpretation where available.

KCDNR staff conducted field sampling over three phases. Specific objectives of each phase of the KCDNR study are summarized in **Table 4.1**.

Table 4.1 STUDY OBJECTIVES

Phase	Sample Period	Primary Objectives
1	August 9-20,1994	a. Determine the areal extent of sediment contamination near the outfalls based on comparison of surface chemistry data to SMS criteria. b. Supplement surface chemistry results with bioassay data to provide information used to assess risks to natural resources and confirm that contaminant concentrations are of concern. c. Collect sediment cores to determine vertical extent of contamination.
1.5	November 7-11, 1995	a. Refine the boundary of the sediment cleanup area at the outer edge of the site based on additional surface chemistry characterization.
2	May 20-21 and June 3, 1996 July 22-26, 1996 September 9-11, 1996	a. Collect additional sediment cores to refine vertical extent of contamination. b. Refine the boundary of the sediment cleanup area around the E-shaped pier and Diagonal Way outfall based on additional surface chemistry characterization. c. Refine the boundary of the sediment cleanup area around the outfalls based on bioassay testing and additional surface chemistry characterization.

4.2 FIELD AND LABORATORY METHODS

This section briefly describes the field and laboratory methods utilized during the KCNDR Duwamish/Diagonal outfall characterization. For a detailed description of study design, field procedures, and analytical methods, refer to the following documents:

- EBDRP (1994c). *Duwamish/Diagonal Sampling and Analysis Plan*. Prepared for EBDRP by King County Department of Metropolitan Services. September 1994.
- EBDRP (1996a). *Duwamish/Diagonal Phase II Sampling and Analysis Plan.* Prepared for EBDRP by King County Department of Metropolitan Services. April 1996.

- Weston (1999). *Site Inspection Report, Lower Duwamish River (RK 2.5 to 11.5), Seattle, Washington.* Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington. April 1999.

The Duwamish/Diagonal Sampling and Analysis Plans (SAPs) were developed in accordance with requirements of the SMS and the *Sediment Cleanup Standards User Manual* (Ecology 1991), and were reviewed and approved by the SRTWG and the EBDRP Panel prior to implementation.

4.2.1 Field Methods

KCDNR staff performed all field sampling during Phases 1, 1.5, and 2. Specific elements of the field studies are summarized below. Field methods used during the EPA study are summarized in their report (Weston 1999).

4.2.1.1 Sampling Design

The sampling design for the Phase 1 sediment chemistry surface grab stations was based on depth contour strata and systematic spacing. Four strata were chosen that run approximately parallel to shore: 1) intertidal mudflat northeast of the Diagonal Way outfall; 2) the area between 0 and -10 feet MLLW (0 to 3 m); 3) the area between -10 and -25 feet MLLW (3 to 8 m); and 4) the area deeper than -25 feet MLLW (8 m) and to the east edge of the dredged channel. From the outfall, the sampling grid extended approximately 300 feet downriver, 800 feet upriver, and 200 feet offshore, at 100-foot (33-m) intervals.

Focused sampling designs were applied to the Phase 1.5 and Phase 2 field efforts to refine the boundaries of the contaminated areas. Phase 1.5 stations were outside or on the perimeter of the Phase 1 sampling design to assess the extent and composition of pollutants at distance from the outfalls. The Phase 2 Study Area was divided into three areas: 1) downstream (to the north), where the surface boundary would be defined by biological testing; 2) the vicinity of the E-shaped pier at the cement shipping facility, where relatively minor contamination would be evaluated using biological testing; and 3) upstream (to the south), where chemistry testing would be used to refine the boundaries of an area with high concentrations and different chemicals than identified in the other areas.

Sediment cores were collected during Phase 1 and Phase 2 to assess the vertical extent of contamination and estimate the volume of contaminated sediments. This information was necessary to support design of dredging plans and the evaluation of disposal options. Two cores directly offshore of the Duwamish and Diagonal outfalls were taken during Phase 1. Phase 2 cores were taken throughout the nearshore area that was considered to have the highest potential for remediation. No cores were taken in the dredged river channel because it was assumed the area would eventually be dredged by the USACE.

4.2.1.2 Surface Sediment Collection

Surface sediment chemistry and bioassay samples were collected with a 0.l square meter (m^2) van Veen grab. A 10-cm deep subsample from the center of the grab sample was taken for analysis. Two grabs were composited at each station to form one sample where only sediment chemistry analyses were performed. Samples for both chemistry and bioassay analyses were composited from three grabs. Samples were rejected if they failed to meet sample acceptability criteria specified in *Puget Sound Estuary Program Protocols* (PSEP 1991), and the *Duwamish/Diagonal Sampling and Analysis Plans.* (EBDRP 1994c; EBDRP 1996a)

Sediment grab samples were processed according to the following sequence, when applicable:

1. Total sulfides, acid volatile sulfides, and pH/Eh/temperature measurements were conducted on the first acceptable grab.
2. The top 10 cm was then composited from several grabs.
3. Sample containers were then filled in the following order from the composite: (a) methyl mercury; b) metals; c) organotins; d) BNA (Base/Neutral/Acid)/pesticides/PCBs; e) chlorinated benzenes; f) PCB congeners; g) percent solids and total organic carbon; h) particle size distribution; i) interstitial salinity; and j) bioassays.

Samples were kept on board in ice chests and transported to the King County Environmental Laboratory (KCEL) at the end of each field day, where they were stored in accordance with conditions specified in the Duwamish/Diagonal SAP.

The van Veen grab sampler was cleaned between stations using the following sequence: 1) soap and water scrub; 2) triple rinse with site water; and 3) final in-stream site water rinse. These procedures were an exception to the PSEP protocols, but were implemented to avoid the use of both acetone and methylene chloride in the field. Stainless steel bowls and utensils were cleaned at the laboratory prior to field use.

4.2.1.3 Subsurface Sediment Collection

Sediment cores were collected by three methods. During Phase 1, a thin-walled, 4-inch (10-cm) diameter aluminum core tube was driven vertically into the sediments by a diver using a pneumatic jackhammer. The two cores (DUD006 and DUD020) were divided into 6-inch (15-cm) segments for analysis. Every 6-inch section was analyzed within the top three feet of the core and every other 6-inch section was analyzed within the bottom two feet of the core.

Phase 1 cores were processed according to the following sequence:

1. Determine the top and bottom of the sediment within the core and divide the core into 6-inch sections accordingly. Extrude the sample and exclude the sediment in contact with the edges and ends of each section.

2. Obtain a sample for acid volatile sulfides from the entire length of each 6-inch section.

3. Mix the remaining sample from each section thoroughly. Sample containers were then filled in the following order from the mixture: a) BNA/pesticides/PCBs, b) metals, c) percent solids and TOC, and d) particle size distribution.

Two methods of coring were employed during Phase 2. The core at station DUD206 was obtained using a hand auger during a low tide. The other cores were obtained with a vibracorer operated remotely from a vessel by the contractor, Marine Sampling Systems, with KCDNR personnel aboard. Cores were divided into compaction-corrected 3-foot (0.91 m) sections at the laboratory. Some sections of cores were archived based on the following scheme: 1) the bottom section (i.e., 6 to 9 feet) was archived for cores within the most contaminated areas; and 2) the two lowest sections (i.e., 3 to 6 feet and 6 to 9 feet) were archived for cores far downstream of the Duwamish/Diagonal outfalls or within the central unit where contamination was lower. The archived samples were kept for possible future analysis. Most of the archived samples were eventually analyzed for PCBs and conventionals.

Two of the Phase 2 cores (DUD027 and DUD254) were analyzed for disposal option tests in addition to more routine analyses. The Phase 2 cores were processed according to the following sequence:

1. Divide the core into compaction-corrected 3-foot (0.91-m) sections. Extrude the sample and exclude the sediment in contact with the edges and ends of each section.

2. Obtain samples for toxicity characteristic leaching procedure (TCLP)-volatiles, TPH-gasoline, and reactivity from the undisturbed entire length of each section.

3. Mix the remaining sample thoroughly.

Sample containers were then filled in the following order from the mixture: a) BNA/pesticides/PCBs; b) chlorobenzenes; c) metals; d) percent solids and TOC; e) particle size distribution; f) TCLP-organics and TCLP-metals; g) TPH-Hydrocarbon Identification (HCID); and h) ignitability and corrosivity. Core sections were assigned unique laboratory numbers. Cores were kept onboard and transported to KCEL at the end of each field day, where they were processed and individual samples were stored in accordance with conditions specified in the Duwamish/Diagonal SAP.

The procedure used to section Phase 1 cores differs in two significant ways from that used for Phase 2. First, Phase 1 cores were sectioned into 6-inch sections, compared to the 3-foot sections of Phase 2. Second, Phase 2 core sections were corrected for compaction (difference between penetration and recovery) while the Phase 1 sections were not. For these reasons, Phase 1 and Phase 2 core sections are not directly comparable.

All coring equipment was cleaned prior to field sampling. Core tubes were cleaned using the following sequence: 1) soap and water scrub; 2) triple rinse with tap water; and 3) final in-stream site water rinse.

4.2.1.4 Reference Stations

Two reference samples were collected by KCDNR during Phase 2 to assist with bioassay interpretation. The reference stations (CR101 and CR102) were established at Carr Inlet in areas with known sediment quality and successful toxicity reference sediments where interstitial salinities and grain sizes would be similar to sediments at the investigation site. CR101 was established for comparison to sediments with a high percentage of fines, which includes six of the seven bioassay samples taken from Duwamish/Diagonal. CR102 was established for comparison to coarse sediments, in this case, the sample from DUD206.

4.2.1.5 Station Positioning

During Phase 1 and Phase 1.5, shore-based surveyors directed the survey vessel to pre-determined sampling stations. Surveyors used a combined theodolite and infrared electronic distance measuring instrument (EDMI) manned at shore reference stations. The EDMI targeted onto an Omni prism cluster mounted on the survey vessel, and the survey vessel was directed to within +/- 3 m of the pre-determined station. The sampler was deployed when the vessel was in an acceptable location and the surveyors recorded the position of the vessel after the grab sampler (or diver) hit bottom. Measured angles and ranges were converted to horizontal plane coordinates referenced to the Washington coordinate system, north zone, 1983 North American Datum (NAD83). Depths are referenced to MLLW, with corrections based on tide tables.

A Differential Global Positioning System (GPS) was used for positioning during Phase 2 grab and core sampling operations. The Coast Guard base station was used for real-time corrections, allowing approximately 1-m accuracy. During grab sampling, the GPS receiver antenna was mounted atop the crane deploying the instrument, negating the need for offset calculations. Grab sampling locations should be accurate within 10 feet (3 m). The GPS antenna was mounted above the cabin during coring, requiring a correction based on a recorded compass bearing and assumed 30-foot offset. Coring locations are expected to be accurate within 20 feet (7 m). Depths are referenced to MLLW with corrections based on tide tables.

Station locations for Phase 1, Phase 1.5, Phase 2, and EPA stations in the study area are illustrated in **Figure 4-1.** Overall, a total of 58 surface sediment stations and 14 sediment core stations were sampled during the KCDNR investigation. Actual station coordinates and sediment elevations are presented in **Appendix J**.

4.2.1.6 Field Documentation

KCDNR sample documentation included 1) chain-of-custody forms, which were maintained throughout the laboratory analyses; 2) field sheets maintained by the KCEL; and 3) sampling notes maintained by the Project Manager. Sampling notes are not available for the Phase 2 bioassay samples.

4.2.2 Laboratory Methods

Laboratory methods were selected to provide data for comparison to SMS criteria. In addition, some sediments were tested for waste classification to evaluate disposal and beneficial use options. KCEL conducted most of the chemical testing; however, they also subcontracted some analyses to the following laboratories: 1) Beak Consultants of Kirkland, Washington; 2) AmTest Inc., of Redmond, Washington; 3) Frontier Geosciences of Seattle, Washington; 4) MEC Analytical Systems, Inc., of Carlsbad, California; 5) Battelle Marine Sciences Laboratory of Sequim, Washington; and 6) Laucks Testing Laboratories, Inc., of Seattle, Washington.

Test methods and laboratories used for this study are presented in **Table 4.2**. Because not all test methods were conducted during each phase, a complete log of analyses performed on each sample, at each station, during each phase is included in **Appendix K.**

Holding times and detection limits for this study were specified in the SAPs (EBDRP 1994c and 1996a). Holding times were based primarily on Ecology guidance originating from the *PSDDA Third Annual Review Meeting* (ARM 1991). The KCEL distinguished between a method detection limit (MDL) and a reporting detection limit (RDL) for most analyses. The MDL represents the lowest concentration at which sample results are provided and the RDL is defined as the minimum concentration of a constituent that can be reliably quantified. For this report, the MDL value was used to represent the limit of detection. Some data (e.g., particle size, reactivity, and methyl mercury) are available with an MDL only, in accordance with laboratory policies. Ignitability, corrosivity, and Washington TPH-HCID results are qualitative, so their reporting requirements are different.

Table 4.2 TEST METHODS AND LABORATORIES

Parameter	Method	Laboratory
Conventionals		
Acid Volatile Sulfides	PSEP	AmTest
Total Solids	SM 2540-B	KCEL
Total Organic Carbon (TOC)	SM 5310B, PSEP Prep	KCEL
Ammonia Nitrogen	SM 4500-NH3-N	KCEL
Particle Size Distribution (PSD)	PSEP/ASTM 422	AmTest
Interstitial Salinity	Refractometer	Beak (Phase 1) MEC (Phase 2)
Metals		
Total Metals	EPA 3050/6010; Inductively Coupled Plasma	KCEL
Total Mercury	EPA 7471; Cold Vapor Atomic Absorption	KCEL
Methyl Mercury	In-house method	Frontier Geosciences
Organics		
Base/Neutral/Acid Extractable (BNAs)	EPA 3550/8270	KCEL
Polychlorinated Biphenyls (PCBs)	EPA 3550/8080	KCEL
Chlorinated Pesticides	EPA 3550/8080	KCEL
Tributyltin (TBT)	Grignard (NOAA 1989) (Unger et al. 1986)	Laucks (Phase 1) Battelle (Phase 1.5)
Chlorinated Benzenes	EPA 3550/8270; and ion trap detector or SIM	KCEL
Waste Characterization		
Total Petroleum Hydrocarbons (TPH)	WTPH-HCID	KCEL
TCLP-Volatiles, BNAs, Pesticides, Metals	EPA SW-846	KCEL
Reactivity-Cyanide and Sulfide	EPA SW-846	AmTest
Ignitability and Corrosivity	EPA SW-846	AmTest
Bioassays		
Amphipod (*Eohaustorius estuarius)*	10-day mortality; PSEP 1995	Beak (Phase 1)
Amphipod (*Rhepoxynius abronius*)	10-day mortality; PSEP 1995	MEC (Phase 2)
Echinoderam *(Dendraster excentricus)*	Larval mortality/abnormality; PSEP 1995 (Phase 1); PSEP 1995 (Phase 2)	Beak (Phase 1) MEC (Phase 2)
Polychaete *(Neanthes arenaceodentata)*	20-day growth; PSEP 1995 (Phase 1); PSEP 1995 (Phase 2)	Beak (Phase 1) MEC (Phase 2)

Collection, analysis, and reporting of sediment toxicity (bioassays) were conducted in accordance with PSEP (1995) and WAC 173-204-315, -320 and -520 (Ecology 1995a). The bioassay test organisms were selected based on grain size, interstitial salinity, and TBT tolerance. Most of the bioassays were performed on sediments with 50 to 97 percent fines, with one as low as 8 percent fines. Interstitial salinity values of 21 to 33 ppt were measured at the site. Based on this range, it was appropriate to use marine bioassays and adjust salinity upward as needed to meet the testing protocols of 25 ppt. High concentrations of TBT (greater than 400 parts per billion [ppb]), which could potentially cause toxicity unrelated to SMS-criteria parameters, were found at the perimeter of the site.

West Beach sand was collected from Whidbey Island, Washington, for use as a negative control in the polychaete and amphipod test. Seawater was used for the negative control for the echinoderm test. Reference sediments for all three organisms were collected from Carr Inlet, Washington. Positive controls with cadmium chloride were conducted for all three organisms.

4.3 QUALITY ASSURANCE / QUALITY CONTROL RESULTS

KCEL prepared a Quality Assurance (QA) review for data collected and analyzed during Phases 1, 1.5, and 2. The QA1 reviews were conducted in accordance with guidelines established through the Puget Sound Dredged Disposal Analysis (PSDDA) program, primarily in the *PSDDA Guidance Manual, Data Quality Evaluation for Proposed Dredged Material Disposal Projects*. Additionally, many of the approaches incorporated in the QA1 Reviews have been established through collaboration between KCEL and Ecology's Sediment Management Unit.

Laboratory QA1 Review reports include:

- Metro Environmental Laboratory (1994). *Quality Assurance Review for Duwamish/Diagonal Sediment Cleanup Study, Elliott Bay Duwamish Restoration Program*. December 23, 1994 (Phase 1).
- KCEL (1995). *Quality Assurance Review for Duwamish/Diagonal CSO, Pre-Phase II Marine Sediment Sampling*. December 28, 1995.
- KCEL (1996a). *Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study, Phase II Marine Sediment Core Sampling*. August 21, 1996.
- KCEL (1996b). *Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study Phase II Marine Sediment Grab Sampling and Study, Phase II Marine Sediment Core Sampling*. November 12, 1996.
- KCEL (1997a). *Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study, Phase II Archived Sediment Core Samples*. February 7, 1997.
- Striplin Environmental Associates (1997). *Duwamish Diagonal Bioassay Review*. February 11, 1997.
- KCEL (1997b). *Phase II Bioassay Review*. December 10, 1996 and January 9, 1997.

Complete laboratory QA1 Review reports including definitions of the qualifiers used, are included as **Appendix L**. Qualified data indicate higher uncertainty (higher variability) in reported results. Qualified results should be used with caution for decision-making purposes. Modifications to laboratory qualifiers included: 1) laboratory qualifiers reported as <MDL were converted to a U qualifier (undetected); and 2) laboratory qualifiers reported as <RDL were converted to a J qualifier (tentatively detected).

The chemical data were reviewed for the following parameters, where applicable: 1) completeness; 2) methods; 3) target list; 4) detection limits; 5) holding times and conditions; 6) method blanks; 7) standard reference materials; 8) replicates; 9) units and significant figures; 10) matrix spikes; and 11) surrogates. The bioassay data were reviewed against PSEP protocols, and tables and narrative sections were evaluated for accuracy against bench sheet data.

Overall, no chemical data were rejected as unusable for the Cleanup Study Report, although some data were qualified. Conversely, Phase 1 bioassay data were rejected for regulatory purposes based on Ecology review (Michelsen 1995). Phase 1 bioassay data are not included in this report. Major issues identified in the QA1 Reviews are presented below.

4.3.1 QA 1 Review of Phase 1 Data

4.3.1.1 Particle Size Distribution (PSD)

Five triplicate samples were analyzed to evaluate precision. The percent Relative Standard Deviation (% RSD) for a number of phi sizes were outside the acceptable quality control (QC) range. Poor precision was observed throughout the phi size range without a consistent pattern; therefore, high or low bias in reported results could not be determined. All PSD data were qualified as estimated (E).

4.3.1.2 Acid Volatile Sulfides

Seven triplicate samples were analyzed to evaluate precision. The % RSD values were within the acceptable QC range for five of the seven triplicate samples. In many cases, the sample triplicates were analyzed from two different sample containers collected for the same sample. It appears that some of the variability may be associated with sample containers and may not be entirely due to analytical performance. All acid volatile sulfides data were qualified as estimated (E).

4.3.1.3 Metals

The following QC issues were identified for metals analysis of Phase 1 data:

- In general, reported Relative Percent Differences (RPD) for replicate samples are within the acceptable QC range and have not resulted in data qualification. Data associated with replicate RPD of greater than 20 percent were qualified as estimated. The high RPD values for arsenic, copper, and lead in Samples 4378-3 to 4378-10 and 4378-12 to 4378-17 can be attributed to the observed difficulty in obtaining a homogeneous subsample from these samples, and indicate higher uncertainty (higher variability) in reported results.

- Data associated with matrix spike recoveries outside the acceptable QC range were qualified as estimated with either the G (low recovery) or L (high recovery) flag.

Poor spike recovery values were reported for copper (54 percent), lead (137 percent), antimony (25 percent, 20 percent, 33 percent, and 37 percent), and zinc (0 percent and 69 percent). Zinc results associated with a spike recovery value of 0 percent were qualified as X (very low recovery).

4.3.1.4 Organics

The following QC issues were identified for organics analysis of Phase 1 data:

- Extracts used to determine chlorobenzenes and related compounds by ion trap GC/MS were analyzed beyond the SAP-specified holding time. All chlorobenzene and related compound results were qualified as estimated. The detection limit for hexachlorobenzene in Samples 4288-12 and 4288-13 exceeded the SQS due to low levels of TOC in the samples.

- Di-n-butyl phthalate, butyl benzyl phthalate, bis (2-ethylhexyl) phthalate, 1,2-dichloro-benzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene were detected in at least one method blank. Associated data were qualified with a B (contamination reported in the blank).

- Elevated detection limits were reported for butyltin isomers in samples 4288-4, 4288-11, 4288-24, 4288-30, and 4288-31 due to dilutions necessary to control for matrix interferences and chromatography problems.

- Low surrogate recovery was reported for the pesticide analysis for Sample 4378-6. All pesticide results for this sample were qualified as estimated.

- Isolated instances of replicate RPD values outside the acceptable QC range were reported for BNA analyses. Results for acenapthene, 4-nitroanaline, and benzoic acid in affected samples were qualified as estimated.

4.3.1.5 Bioassays

The following QC issues were identified for bioassay analysis of Phase 1 data:

- Ecology reviewed the reported results for the three sediment bioassays and determined that the data sets were unusable for regulatory purposes (Michelsen 1995). Data for two of three tests were considered invalid, and only the amphipod bioassay data appeared unaffected.

- Three QC issues were identified that affected the usability of results: 1) results of the positive control tests for the echinoderm larval bioassay showed that the larvae survived well above the normal control range and did not show a dose-response pattern when exposed to the control toxicant; 2) the initial starting weight of all of the polychaete Neanthes worms was lower than recommended by PSEP protocols resulting in low growth rates that did not meet SMS performance standards; and 3) numerous water quality exceedances were noted for dissolved oxygen, pH, and salinity during the above testing.

- Because two test results were considered invalid, the Phase 1 bioassay data are unusable for comparison to SMS biological criteria and are not considered further in this report.

4.3.2 QA 1 Review of Phase 1.5 Data

4.3.2.1 Metals

The following QC issues were identified for metals analysis of Phase 1.5 data:

- The Standard Reference Material (SRM) recovery value for antimony was less than 80 percent (24 percent) and the matrix spike recovery value was less than 75 percent (28 percent). All sample results for antimony were qualified as estimated (G, low bias).

- Matrix spike recovery values were outside the accepted QC range (75 percent to 125 percent) for sodium (57 percent) and aluminum (531 percent). Associated sample results were qualified as estimated (G, low bias; L, high bias).

- Laboratory duplicate RPD values outside the accepted QC range (greater than 20 percent) were reported for aluminum (38 percent) and arsenic (38 percent). Associated sample results were qualified as estimated (E).

4.3.2.2 Organics

The following QC issues were identified for organics analysis of Phase 1.5 data:

- Chlorobenzene surrogate recovery values for all samples were low (0 to 32 percent). Results for sample L7279-1 were qualified as very biased (X). Results for the remaining samples were qualified as estimated (G, low bias).

- The SRM recovery value for several BNA compounds were outside the accepted QC range of 80 to 120 percent (55 to 72 percent and 143 percent). All sample results were qualified as estimated (G, low bias; L, high bias). Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene were also outside the accepted QC range of 75 to 125 percent (41 to 46 percent). Results for all samples were qualified as estimated (G, low bias).

- BNA matrix spike recovery values for several compounds were outside the accepted QC range of 75 to 125 percent (0 to 47 percent and 170 to 172 percent). All sample results were qualified as estimated (X, very biased; G, low bias; L high bias).

- A laboratory duplicate RPD value exceeding the QC limit of 100 percent (115.9 percent) was reported for Aroclor 1260, possibly due to inadvertent spiking of the duplicate sample. All sample results for Aroclor 1260 were qualified as estimated (E).

4.3.3 QA 1 Review of Phase 2 Surface Sediment Data

4.3.3.1 Metals

The following QC issues were identified for metals analysis of Phase 2 surface sediment data:

- The 28-day mercury holding time was exceeded for Samples 9446-1 through 9446-2 (Carr Inlet reference samples). Associated data were qualified with the H flag.

- The SRM recovery value for antimony was less than 80 percent (33 percent) and the matrix spike recovery value was less than 75 percent (27 percent). All sample results for antimony were qualified as estimated (G, low bias). The SRM recovery value for cadmium was greater than 120 percent (125 percent). All sample results for cadmium were qualified as estimated (L, high bias).

- Matrix spike recovery values for aluminum, antimony, iron, and silver in Samples 8542-8 through 8542-10 were outside the accepted QC range of 75 percent to 125 percent (410 percent, 27 percent, 67 percent, and 30 percent, respectively). Matrix spike recovery values for aluminum, antimony, and iron in Samples 9443-1 through 9443-8 were outside the accepted QC range 75 percent to 125 percent (aluminum 163 percent, antimony 25 percent, and iron 72 percent). Matrix spike recovery values for aluminum, antimony, and iron in Samples 9446-1 through 9446-2 were outside the accepted QC range 75 percent to 125 percent (aluminum 60 percent, antimony 37 percent, and iron 67 percent). Associated sample results were qualified as estimated (G, low bias; L, high bias).

4.3.3.2 Organics

The following QC issues were identified for organics analysis of Phase 2 surface sediment data:

- Bis (2-ethylhexyl) phthalate and butyl benzyl phthalate were detected in the method blank associated with Samples 8542-9 through 8542-10. Associated data were qualified with a B (contamination reported in the blank).

- The SRM recovery values for several BNA compounds were outside the accepted QC range of 80 percent to 120 percent (13 percent to 72 percent). All sample results for these compounds were qualified as estimated (G, low bias).

- The PCB SRM recovery value was less than 80 percent (60 percent) for Aroclor 1254. Associated sample data were qualified as estimated (G, low bias).

- Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene, were outside the accepted QC range of 75 percent to 125 percent (32 percent to 38 percent). Results for Samples 8542-8, 8542-9, and 9443-1 through 9443-8 were qualified as estimated (G, low bias).

- Matrix spike results for numerous BNA compounds in Samples 8542-8 through 8542-10, 9446-1, 9446-2, and 9443-1 through 9443-8, were outside the accepted QC range of 75 percent to 125 percent (0 percent to 48 percent). Results for these compounds were qualified as estimated (X, very biased; or G, low bias).

- Laboratory RPD values for 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,2,4-trichlorobenzene, and hexachlorobenzene were greater than the QC limit of 100 percent (133 percent to 200 percent) for the duplicate Samples 8542-8 through 8542-10. Associated sample data for these compounds were qualified as estimated (E).

4.3.4 QA 1 Review of Phase 2 Subsurface Data

4.3.4.1 Metals

The following QC issues were identified for metals analysis of Phase 2 subsurface data:

- The 28-day sample holding time for mercury was exceeded by seven days for Samples 8542-32 through 8542-39. Mercury analytical results for these samples were qualified with an XHT flag indicating an exceedance of holding time. The 28-day mercury holding time was exceeded for Samples 9142-1 through 9142-3. Associated data were qualified with the H flag.

- The SRM recovery value for antimony was less than 80 percent (33 percent and 33 percent), and the matrix spike recovery values were less than 75 percent (35 percent and 27 percent). All sample results for antimony were qualified as estimated (G, low bias).

- Matrix spike recovery values were outside the accepted QC range of 75 percent to 125 percent for mercury (138 percent), sodium (53 percent), and aluminum (174 percent). Associated sample results were qualified as estimated (G, low bias; L, high bias). Matrix spike recovery values for antimony, silver, sodium, and mercury in Samples 9142-1 through 9142-3 were outside the accepted QC range of 75 percent to 125 percent (22 percent, 60 percent, 66 percent, and -44 percent, respectively). Associated sample results were qualified as estimated (X, very biased; G, low bias).

- Laboratory duplicate RPD values exceeding the QC limit of 20 percent were reported for copper (29 percent), lead (32 percent), and mercury (64 percent) for samples 8542-32 through 8542-39. Associated sample results were qualified as estimated (E).

4.3.4.2 Organics

The following QC issues were identified for organics analysis of Phase 2 subsurface data:

- Bis (2-ethylhexyl) phthalate was detected in the method blank associated with Samples 8542-12 through 8542-18 and 8542-35 through 8542-38. Di-n-butyl phthalate was detected in the method blank associated with Samples 9142-1 through 9142-3. Associated data were qualified with a B (contamination reported in the blank).

- Chlorobenzene surrogate recovery values for all samples were low (2 percent to 32 percent). Results for Samples 8542-15, 8542-16, and 8542-30 were qualified as very biased (X). Results for the remaining samples were qualified as estimated (G, low bias). Chlorobenzene surrogate recovery values were less than the 50 percent QC limit (25 percent to 32 percent) in Samples 9142-1 through 9142-3. All chlorobenzene results in these samples were qualified as estimated (G, low bias).

- BNA surrogate recovery values for several samples were less than 50 percent (15.5 percent to 49.5 percent). Results for these samples were qualified as estimated (G, low bias).

- The SRM recovery values for several BNA compounds were outside the accepted QC range of 80 percent to 120 percent (14 percent to 67 percent). All sample results for these compounds were qualified as estimated (G, low bias).

- Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene were outside the accepted QC range of 75 percent to 125 percent (29 percent to 49 percent). Results for several samples were qualified as estimated (G, low bias).

- Matrix spike results for numerous BNA compounds in Samples 8542-19, 8542-20, 8542-26, and 8542-31 through 8542-34, and 9142-1 through 9142-3, were outside the accepted QC range of 75 percent to 125 percent (0 percent to 50 percent). Results for these compounds were qualified as estimated (X, very biased; G, low bias; or L, high bias).

- Matrix spike results for PCB Aroclor 1260 were outside the accepted QC range of 50 percent to 150 percent (36 percent and 43 percent, and 159 percent). Results for Samples 8542-12 through 8542-27, and 8542-29 through 8542-39, and 9142-1 through 9142-3, were qualified as estimated (G, low bias; or L, high bias).

4.3.5 QA 1 Review of Phase 2 Bioassay Data

Two acute effects tests (10-day amphipod and echinoderm larval) and one chronic effects test (20-day *Neanthes* growth) were performed on seven test sediments (DUD200 through DUD206), two control sediments (Control A and Control B), and two reference sediments (P9446-1 and P9446-2). MEC Analytical Systems, Inc. (MEC) of Carlsbad, California performed the bioassays. Laboratory methods, data quality issues, and test results are presented in a final report to King County (MEC 1996; **Appendix L**). The laboratory used methods described in MEC bioassay protocols and PSEP (1995). MEC and KCDNR conducted Quality Assurance reviews of the Phase 2 bioassay data (**Appendix L**).

Deviations from the protocol and/or SAP include:

4.3.5.1 Juvenile Polychaete

- Water quality measurements were taken for each sample every third day, as specified in PSEP, instead of every day as specified in the SAP.

- Reference sediment growth rates were less than the SMS growth criterion of 80 percent of control growth.

4.3.5.2 Amphipod

- Sample preparation, sample identification, or another error occurred with the positive control test.

4.3.5.3 Echinoderm Larval

- The first control did not meet the protocol specification so new animals were received and testing was repeated. Sediment samples were held four days past the 14-day holding time at the start of the second test.

- The positive control sample was not stored and handled correctly/properly.

4.4 SURFACE SEDIMENT CHEMISTRY RESULTS

Appendix A includes surface sediment (i.e., 0 to 10 cm depth) chemistry results for conventionals and SMS chemicals. Concentrations for SMS chemicals are compared to SMS criteria defined in WAC 173-204, which provides sediment quality criteria for the following effects levels:

- ***SQS criteria:*** Establishes a sediment quality that will result in no adverse effects on biological resources (WAC 173-204-320).
- ***CSL criteria:*** Establishes minor adverse effects levels, above which station clusters of potential concern are defined as cleanup sites (WAC 173-204-530), and also establishes minimum cleanup levels (MCULs) to be used in evaluation of cleanup alternatives (WAC 173-204-560).

Because SMS criteria for most nonionizable organic chemicals are listed in units of mg/kg organic carbon normalized (OCN), laboratory chemical data which were typically expressed as µg/kg DW (ppb DW) were first changed to mg/kg DW (ppm DW) and then converted to mg/kg OC, using the following equation:

$$\text{mg/kgOC} = \frac{\text{mg/kgDW}}{\text{TOC}}$$

where TOC = percent TOC expressed as the decimal equivalent.

This conversion was calculated for each station, based on station-specific TOC data. For original DW concentrations of organic chemicals, refer to **Appendix A**.

Ecology has indicated that for low TOC sediments (e.g., 0.1 to 0.2 percent), comparison of nonionizable organic concentrations to OC-normalized SMS criteria may not be appropriate since the low TOC would not control chemical bioavailability. For these conditions, Ecology may allow a comparison of DW concentrations to DW Apparent Effects Threshold (AET) values on a site-specific basis to evaluate sediment toxicity (Michelsen 1992). AET values have been developed for 64 organic and inorganic chemicals based on the observed relationships between biological effects and chemical concentrations (PSEP 1988). Therefore, in addition to the SMS criteria comparison presented in **Appendix A**, an additional comparison to LAET values of four biological indicators is presented in the second set of tables in **Appendix A**, for stations with TOC concentrations less than 0.2 percent. Comparison to LAET values were used as an SQS surrogate, while comparison to the second-lowest AET (2LAET) values was used as a CSL surrogate.

For this Cleanup Study Report, the chemical summing method for chemical groups (i.e., total LPAHs, total HPAHs, total benzofluoranthenes, and total PCBs) followed SMS procedures, which include: 1) using the highest detection limit reported for an individual chemical in a group when all chemicals are undetected; and 2) summing only the detected values when one or more chemicals in a group are detected.

Preliminary review of surface sediment chemistry data indicated that three distinct contamination areas are apparent for the site. The area adjacent to the Duwamish/Diagonal outfalls are characterized by elevated levels of several contaminants predominated by bis (2-ethylhexyl) phthalate. This area is referred to as the North Inshore Area. The area offshore of the cement plant dock and old treatment plant outfall is characterized by elevated levels of several chemicals dominated by PCBs, phthalates, and chlorinated benzenes. This area is referred to as the South Inshore Area. The third area is the dredged river channel located at the offshore edge of the two inshore areas. This entire channel area is dominated by PCB exceedances, but a few other chemicals also have exceedances.

4.4.1 Conventionals

4.4.1.1 Total Organic Carbon

Surface sediment TOC concentrations ranged from 0.08 to 9.42 percent; for comparison, a range of 0.5 to 3 percent is typical for Puget Sound marine sediments (Michelsen 1992). **Figure 4-2** illustrates the spatial distribution of TOC values. Maximum concentrations were reported near the former City treatment plant outfall and south of the Duwamish Outfall. The following Duwamish/Diagonal surface sediment stations are characterized by low TOC concentrations (less than 0.2 percent) and are compared to AET values in addition to SMS criteria:

- DUD013
- DUD015

Both of these stations are located in a sandy nearshore area adjacent to the Diagonal Way CSO/SD outfall, in the South Study Area.

4.4.1.2 Particle Size Distribution

Particle size distribution data are reported in **Appendix A** as percentages of gravel, sand, silt, and clay. In addition, the distribution of percent fines (silt + clay) is illustrated in **Figure 4-3** to indicate areas of deposition and scouring. Generally, the coarsest sediments identified in the Study Area (less than 20 percent fines) were located in the intertidal stations. Finer sediments (greater than 60 percent fines) were located closer to the dredged river channel stations where sediment deposition appears more pronounced.

4.4.1.3 Salinity

Salinity was measured in 12 surface sediment samples collected during Phase 1. Salinity concentrations ranged from 21 to 27 ppt. In comparison, Pre-Phase 1 sediment salinity concentrations ranged from 21 ppt (intertidal sediment) to 33 ppt (deep water sediment). The SMS defines sediments with porewater concentrations greater than 25 ppt salinity as "marine sediments," while those with porewater concentrations between 0.5 and 25 ppt salinity are defined as "low salinity sediments." SMS "marine" sediment quality criteria are used to evaluate site data, including "low salinity sediments." "Low salinity sediment" criteria are not available. In addition, salinity data were used to select appropriate bioassay test organisms and test conditions. Salinity data are reported in **Appendix A.**

4.4.2 Inorganics

Detected inorganic chemicals exceeding SMS criteria in surface sediment samples for the North and South Inshore Areas and dredged channel are summarized in **Tables 4.3, 4.4, and 4.5** respectively. Methyl mercury represented a small fraction (0.10 to 1.4 percent) of the total mercury content for Phase 1 samples (**Appendix A**). SQS/CSL inorganic chemical exceedances were dominated by mercury and zinc in the North Inshore Area, by mercury in the South Inshore Area and by mercury in the channel area.

Of the three SQS zinc exceedances reported for the North Inshore Area, two of these were associated with stations located away from the outfalls. Therefore, zinc does not appear to represent a contaminant of concern due to outfall discharges. This information tends to contradict the recontamination modeling results presented in **Section 3.4.1**, which indicated that zinc would have the greatest potential to recontaminate the Study Area following cleanup actions.

4.4.3 Organics

Detected organic chemicals exceeding SMS/AET criteria in surface sediment samples for the North Inshore Area, South Inshore Area, and dredged channel area are included in **Tables 4.3, 4.4**, **and 4.5,** respectively. SQS/CSL organic chemical exceedances were dominated by PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate in all three areas.

Table 4.3 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES [a]
NORTH INSHORE AREA

Chemical	Stations Exceeding SQS Only[b]			Stations Exceeding CSL[b]		
Mercury	DUD016	DUD021	DUD029	DUD004		
Zinc	DUD005		DUD028	--		
1,2-Dichlorobenzene	--			DR008		
1,4-Dichlorobenzene	--			DR007		
Total HPAH	DR006	DR007	DR059	DR008		DR009
Total LPAH	DR007	DR008		DR009		
Total PCBs	DUD001 DUD004 DUD007 DUD016 DUD020 DUD021 DUD022	DUD023 DUD024 DUD029 DUD030 DUD031 DUD042 DUD043	DUD200 DUD201 DUD202 DUD204 DR007 DR059	DUD028 DR006 DR008 DR009		
bis(2-ethylhexyl)phthalate	DUD008 DUD016 DUD029 DUD030 DUD031 DUD200 DUD201			DUD001 DUD002 DUD003 DUD004 DUD005 DUD006 DUD007 DUD009 DUD016(rep)	DUD017 DUD018 DUD019 DUD020 DUD021 DUD022 DUD023 DUD024 DUD028	DUD042 DUD043 DUD202 DUD204 DR007 DR008 DR009 DR059
Butyl benzyl phthalate	DUD001 DUD002 DUD003 DUD004 DUD005 DUD007 DUD008 DUD009	DUD016 DUD017 DUD018 DUD019 DUD021 DUD022 DUD024	DUD042 DUD043 DUD200 DUD202 DUD204 DR006 DR059	DR007 DR008 DR009		
Phenol	DUD020			--		
4-Methylphenol	--			DUD200	DUD204	

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL Exceedances are reported for stations with TOC concentrations > 0.2

Other Notes:
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.4 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES[a]
SOUTH INSHORE AREA

Chemical	Stations Exceeding SQS Only[b]	Stations Exceeding CSL[b]
Cadmium	DUD012	DUD027
Chromium	--	DUD027
Lead	--	DUD027
Mercury	DUD026	DUD012 DUD027
Silver	--	DUD012 DUD027
Zinc	DUD027	--
Total HPAHs	DR011	--
Total PCBs	DUD010 DUD025 DUD205 DUD016 DUD037 DUD209	DUD012 DUD027 DUD026 DR011
1,2,4-Trichlorobenzene	DUD012	DUD027
1,2-Dichlorobenzene	--	DUD012 DUD027
1,4-Dichlorobenzene	DUD015	DUD027
2-Methylnaphthalene	DUD027	--
4-Methylphenol	--	DUD205 DUD207
bis(2-ethylhexyl)phthalate	DUD016 DUD036 DUD037	DUD010 DUD025 DUD205 DUD012 DUD026 DR010 DUD014 DUD027 DR011 DUD015
Butyl benzyl phthalate	DUD010 DUD025 DR010 DUD012 DUD205 DR011 DUD014	DUD026

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL Exceedances are reported for stations with TOC concentrations >0.2 percent

Other Notes:
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.5 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES
DREDGED CHANNEL AREA

Chemical	Stations Exceeding SQS Only	Stations Exceeding CSL
Arsenic	--	DUD032
Mercury	DUD035 DUD038	DUD032
Zinc	DUD032	
Total PCBs	DUD038 DUD040 DUD045 DUD039 DUD041 DR082	DUD032 DR081 DUD044
Bis (2-ethylhexyl) Phthalate	DUD033 DUD036 DUD045 DUD034 DUD038 DR080 DUD035 DUD040	DUD032 DR081 DUD044 DR082
Butyl Benzyl Phthalate	DUD032 DUD040 DR080 DUD038 DUD044 DR082 DUD039 DUD045	--
Hexachlorobenzene	DUD039 DUD044	--

For those surface sediment stations exhibiting TOC concentrations less than 0.2 percent (i.e., DUD013 and DUD015), no chemicals were detected above the corresponding LAET. These stations are located adjacent to the Diagonal Avenue South SD outfall, in the South Inshore Area.

Although there are no SMS/AET criteria established for TBT, all Phase 1 surface sediment samples were analyzed for TBT due to its high toxicity and due to concentrations found in other studies. Phase 1 results indicate that TBT concentrations were highest offshore and away from the outfalls (**Appendix M**).

4.5 SUBSURFACE SEDIMENT RESULTS

Appendix A includes subsurface sediment chemistry data for conventionals and SMS chemicals. Similar to the surface sediment presentation, concentrations of SMS chemicals are compared to SMS criteria. If TOC values are less than 0.2 percent, SMS chemicals are also compared to AET values in the second set of tables in **Appendix A.**

During Phase 1, two cores (DUD006 and DUD020) were collected adjacent to the Duwamish/Diagonal outfalls. The cores were sectioned into 15-cm segments, which extended down to 150 cm (5 feet) at DUD006 and down to 90 cm (3 feet) at DUD020. Core results were discussed in the Phase 1 Results Summary (**Appendix M**), which indicated the cores were collected from an area of sediment that appears to have been disturbed (mixed) during installation of the Duwamish Siphon. Exceedances of SMS criteria for these core samples are included in **Appendix A**. Results indicated that bis (2-ethylhexyl) phthalate exceeded CSL criteria in every core segment collected at DUD006; therefore, the bottom depth of contamination was not established near the outfall.

During Phase 2, 14 cores (DUD250 to DUD258, DUD260 to DUD262, DUD027, and DUD206) were collected throughout the study area and sectioned into three segments (0 to 90 cm [0 to 3 feet]; 90 to 180 cm [3 to 6 feet]; and 180 to 270 cm [6 to 9 feet]). The top section (0 to 90 cm) was analyzed for all SMS parameters. The middle section (90 to 180 cm) of all but four cores was analyzed for all SMS parameters, while this section from the remaining four cores was archived. A lower section (180 to 270 cm) of each core was archived. Upon analysis and preliminary interpretation of the core data, some of the archived sections were analyzed for PCBs and conventionals. The following discussion focuses on the vertical extent of contamination at the Phase 2 locations, since this provides more representative data for undisturbed core segments.

4.5.1 Conventionals

4.5.1.1 Total Organic Carbon

TOC concentrations ranged between 0.07 to 5.25 percent in the upper section (0 to 90 cm), and between 0.03 to 6.45 percent in the deeper core sections (90 to 180 cm).

The following Duwamish/Diagonal core sections are characterized by low TOC concentrations (less than 0.2 percent) and were compared to AET values in addition to SMS criteria:

- DUD251 (90 to 180 cm) and (180 to 270 cm)
- DUD252 (0 to 90 cm), (90 to 180 cm), and (180 to 270 cm)
- DUD206 (0 to 90 cm)
- DUD257 (180 to 270 cm)
- DUD258 (180 to 270 cm)

Core Stations DUD251, DUD252, DUD257, and DUD258 were located in the North Inshore Area, while Core Station DUD206 was located in the South Inshore Area, in the intertidal area behind the E-shaped pier.

4.5.1.2 Particle Size Distribution

Particle size distribution in core segments was highly variable, possibly due to historical dredging operations for the outfall siphon pipe and for the E-shaped pier area. **Figure 4-4** illustrates the percent sand reported for each core segment. Unlike results reported near the Norfolk CSO located upstream (where sand increased to 93 to 96 percent at core depths exceeding 3 feet), there was no observable trend with depth at the Study Area.

4.5.2 Inorganics

Inorganic chemicals exceeding SMS criteria for core samples collected from the North and South Inshore Study Areas are summarized in **Table 4.6** and **Table 4.7**, respectively.

Table 4.6 SEDIMENT CORE EXCEEDANCES OF SMS CRITERIA OR AET VALUES[a]
NORTH INSHORE AREA

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Cadmium	DUD020	DUD254 DUD255	--	--
Copper	--	--	DUD006	--
Lead	DUD254	DR008	DUD006 DUD020	DUD006 DUD254
Mercury	DUD251 DUD256 DUD258	DUD253	DUD006 DUD020 DUD254 DUD255 DR008	DUD006 DUD254 DUD255 DR008
Silver	--	--	--	DUD255
Zinc	DUD006 DUD020 DR008	DUD254	--	--
Total HPAHs	DUD006 DR008	DUD006 DR008	--	--

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Total LPAHs	DUD006 DR008	--	--	DUD006
Total PCBs	DUD253 DUD254* DUD256 DUD257 DUD258	DUD251[c] DUD255	DUD006 DUD020 DUD250 DUD251 DUD252 DUD255 DR008	DUD006 DUD253* DUD254 DUD256 DUD258 DR008
1,4-Dichlorobenzene	--	DUD006	DUD006 DUD254 DR008	DUD254 DR008
1,2-Dichlorobenzene	--	--	--	DUD006 DR008
bis(2-ethylhexyl)phthalate	DUD253	DUD253 DUD256	DUD006 DUD020 DUD250 DUD251 DUD254 DUD255 DUD256 DUD258 DR008	DUD006 DUD254 DR008
Butyl benzyl phthalate	DUD020 DUD250 DUD251 DUD254 DUD256 DUD258	DUD006 DUD254	DUD006 DR008	DR008
Phenol	DUD006			

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL exceedances are reported for stations with TOC concentrations >0.2 percent.
[c] LAET/2LAET exceedances are reported for stations with TOC concentrations <0.2 percent.
* Also exceeded SQS or CSL in 180 to 270 cm core segment.

Other Notes:
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.7 SEDIMENT CORE EXCEEDANCES OF SMS CRITERIA OR AET VALUES [a]
SOUTH INSHORE AREA

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Mercury	--	--	DUD027 DUD262	DUD027 DUD261
Cadmium	--	DUD027	DUD027	DUD261
Chromium	--	--	DUD027	--
Lead	--	--	DUD027	--
Silver	--	--	DUD027 DUD262	DUD027 DUD261 DUD262
Zinc	--	DUD261	DUD027	--
Total PCBs	--	DUD260 DUD262	DUD027 DUD260 DUD261 DUD262	DUD027 DUD261
1,2-Dichlorobenzene	--	--	DUD262	DUD027 DUD261
1,4-Dichlorobenzene	DUD027 DUD262	DUD027 DUD262	--	--
1,2,4-Trichlorobenzene	DUD027	DUD261	--	DUD027
bis(2-ethylhexyl)phthalate	DUD261	--	DUD027 DUD260 DUD262	DUD027 DUD261
Butyl benzyl phthalate	DUD260	--	--	--

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL exceedances are reported for stations with TOC concentrations >0.2 percent.
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520

SQS/CSL inorganic chemical exceedances were dominated by mercury in the North Inshore Area, and by mercury, cadmium, and silver in the South Inshore Area. The vertical extent of contamination for COCs is discussed further in **Chapter 5.0**.

4.5.3 Organics

Organic chemicals exceeding SMS/AET criteria for core samples collected from the North and South Inshore Areas are summarized in **Table 4.6** and **Table 4.7**, respectively.

SQS/CSL organic chemical exceedances were dominated by PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate in the North Inshore Area, and by PCBs, 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, and bis (2-ethylhexyl) phthalate in the South Inshore Area. The vertical extent of contamination for COCs is discussed further in **Chapter 5.0**.

4.6 SURFACE SEDIMENT BIOASSAY RESULTS

Under the SMS rule, the potential for sediment to cause adverse biological effects is defined by chemical criteria. Biological testing is routinely used to confirm chemical designation of sediments (Ecology 1996). Three of the biological tests specified by the SMS rule were used in this study: 1) 10-Day amphipod; 2) 20-Day juvenile polychaete; and 3) echinoderm embryo. The amphipod and echinoderm bioassays were selected to identify acute effects based on mortality and effective mortality (combined mortality and abnormality) endpoints, respectively. The juvenile polychaete bioassay was selected to evaluate chronic effects based on a growth rate endpoint. The above test species were selected after a review of test sediment and organism characteristics, including sediment grain size and salinity, and organism availability and spawning condition.

As discussed in **Section 4.3** (QA/QC Results), Phase 1 bioassay results were rejected due to testing performance failures and are not considered further. Phase 2 bioassay results and SMS interpretation are summarized in **Table 4.8** and discussed below. Some assumptions relative to the evaluation of the Phase 2 bioassay data included:

- Sample DUD206 (8 percent sand) was compared with Control B, collected from Whidbey Island, in all three bioassays. Sediments from this area have been tested for grain size by the USACE and typically contain approximately 5 percent sand.

- Reference Samples P9446-1 and P9446-2 failed SMS performance criteria for the juvenile polychaete test. The reference mean growth rate endpoint (GRE) must be at least 80 percent of the control mean. The mean GRE for P9446-1 was 0.48 mg/individual/day, and the mean GRE for P9446-2 was 0.60 mg/individual/day. Reference Sample P9446-2 failed the performance criteria by only 0.02 mg/individual/day. Because of this slight exceedance coupled with low standard deviation among replicates, reference Sample P9446-2 was approved by Ecology for comparisons with DUD200 through DUD205.

- Reference sediment Sample P9446-1 was not used for any test/reference comparisons because its grain size was a poor match for the test sediments.

Additional bioassay data are located in **Appendix N** (Sediment Bioassay Results) and **Appendix L** (Laboratory QA1 Reports – Chemistry and Bioassay).

4.6.1 Amphipod Bioassay

The amphipod test using *Rhepoxynius abronius* was conducted for seven test sediments, two reference sediments, and two control sediments. The reference and control sediments met the applicable SMS performance criteria for the amphipod test. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320). The test sediment has a significantly higher ($P \leq 0.05$) mean mortality than the reference sediment, and the test sediment mortality exceeds 25 percent.

- Fails CSL (WAC 173-204-520). The test sediment has a significantly higher ($P \leq 0.05$) mean mortality than the reference sediment, and the test sediment mean mortality is 30 percent greater than the reference sediment.

Amphipod bioassay results are summarized in **Table 4.8**. Station DUD204 was the only station to exceed SMS biological criteria.

4.6.2 Echinoderm Larval Bioassay

The sediment larval test using the echinoderm *Dendraster excentricus* was conducted for seven test sediments, two reference sediments, two control sediments, and one seawater control. The seawater control met the applicable SMS performance criteria for the echinoderm test. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320). The test sediment has a combined abnormality and mortality that is more than 15 percent greater than the reference sediment, and the difference is statistically significant ($P \leq 0.10$).

- Fails CSL (WAC 173-204-520). The test sediment has a combined abnormality and mortality that is more than 30 percent greater than the reference sediment, and the difference is statistically significant ($P \leq 0.10$).

Echinoderm bioassay results are summarized in **Table 4.8**. Station DUD206 was the only station to exceed SMS biological criteria.

Table 4.8 BIOASSAY RESULTS AND SMS INTERPRETATION

		Amphipod Bioassay		20-Day Juvenile Polychaete		Echinoderm Larval	
Station ID	Reference Match	%Mortality (Mean)	SMS Status	Growth Rate (Mean)	SMS Status	%Mort./Abn (Mean)	SMS Status
Test Sediment	P9446-2(Ref)						
DUD200	P9446-2(Ref)	13	Pass	0.60	Pass	32.46	Pass
DUD201	P9446-2(Ref)	21	Pass	0.55	Pass	34.55	Pass
DUD202	P9446-2(Ref)	18	Pass	0.62	Pass	34.97	Pass
DUD203	P9446-2(Ref)	22	Pass	0.59	Pass	32.83	Pass
DUD204	P9446-2(Ref)	26*	>SQS	0.51	Pass	16.63	Pass
DUD205	P9446-2(Ref)	19	Pass	0.54	Pass	15.88	Pass
DUD206	Control B	4	Pass	0.52*	>SQS	34.17*	>SQS
Controls:							
P9446-1(Ref)		6[b]		0.48[d]		27.06[f]	
P9446-2(Ref)		8[b]		0.60[d]		29.04	
Control A		3[a]		0.82[c]		30.96	
Control B		1[a]		0.77[c]		15.24	
Seawater						11.82[e]	

Footnotes:
[a] Control sample passes performance criteria of <10% mortality
[b] Reference sample passes performances criteria of <25% mortality

[c] Control sample passes performance criteria of <10% mortality and mean individual growth rate of $\geq$0.72 mg/individual/day
[d] Reference sample fails performance criteria because reference sediment mean individual growth rate is <80% of the mean individual growth rate in the control
[e] Seawater control passes performance criteria of <30% combined mortality and abnormality
[f] This reference sample exhibited greater than 20% standard deviation (24.8) among the five replicates. The power of the t-test to detect a 20% difference between this reference and a test sediment would not be effective, so this reference is unsuitable for further comparisons.
* Sample result statistically different from reference/control sample.

4.6.3 Juvenile Polychaete Bioassay

The juvenile polychaete bioassay using the test organism *Neanthes arenaceodentata* was conducted for seven test sediments, two reference sediments, and two control sediments. The control sediments met the applicable SMS performance criteria for the polychaete test. Both reference sediments failed performance criteria for the polychaete test; however, one was accepted by Ecology for use since it was very close to the limit. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320): The test sediment has a significantly lower ($P \leq 0.05$) mean individual growth rate than the reference sediment, and is less than 70 percent of the reference sediment.

- Fails CSL (WAC 173-204-320): The test sediment has a significantly lower ($P \leq 0.05$) mean individual growth rate than the reference sediment, and is less than 50 percent of the reference sediment.

Juvenile polychaete bioassay results are summarized in **Table 4.8**. Station DUD206 was the only station to exceed SMS biological criteria.

4.6.4 Bioassay Summary

Overall, Station DUD204 exceeded the SQS biological criteria for the amphipod test, while Station DUD206 exceeded the SQS biological criteria for both the juvenile polychaete and echinoderm larval tests. Because Station DUD206 exceeded two SQS biological criteria, this sample also exceeds the CSL and MCUL per WAC 173-204-520(3)(d). Station DUD206 is located in the intertidal area behind the E-shaped pier (South Inshore Study Area), while Station DUD204 is located just north of the E-shaped pier. Bioassay results were used to refine potential cleanup areas around the Duwamish/Diagonal outfalls (**Chapter 5**).

4.7 WASTE CHARACTERIZATION RESULTS

For initial evaluation of sediment disposal options, two Phase 2 cores were submitted for waste characterization testing. One core from the North Inshore Study Area (DUD254) and one core from the South Inshore Study Area ($DUD027_{PH2}$) were composited into 3-foot (0.91-m) sections. If contaminated sediments are dredged from the river, offsite disposal options will be based on whether the excavated material falls into one of the following waste categories:

- Washington State Dangerous Waste
- Toxic Substances Control Act (TSCA) waste

- TPH-contaminated material

Waste designation criteria for the applicable regulations, as well as initial waste characterization results, are discussed below.

4.7.1 Washington State Dangerous Waste Regulations (Chapter 173-303 WAC)

The purpose of the Dangerous Waste Regulations is to designate those solid wastes that are dangerous or extremely hazardous to the public health and environment and provide guidance on generation, treatment, transportation, and disposal. Relevant sections of the Dangerous Waste Regulations are discussed below.

4.7.1.1 Excluded Categories of Waste (WAC 173-303-071 (3)(k)(i))

Certain categories of waste are excluded from the requirements of WAC 173-303-071 because they are regulated under other state or federal programs. One of these categories is PCB wastes, the disposal of which is regulated under 40 CFR 761.60 (TSCA) (refer to Section 4.7.2).

4.7.1.2 Dangerous Waste Characteristics (WAC 173-303-090)

Dangerous waste characteristics include ignitability, corrosivity, reactivity, and toxicity (using the TCLP). **Table 4.9** presents the results of testing Phase 2 core sections for Dangerous Waste characteristics. These initial results include:

- The flashpoint (measure of ignitability) of all samples was greater than 140° F, indicating low potential for ignitability. Therefore, the sediment does not designate as Dangerous Waste based on the ignitability characteristic criteria.
- The pH (measure of corrosivity) of all samples was approximately neutral (ranging from 7.1 to 8.0), indicating low potential for corrosivity. Therefore, the sediment does not designate as Dangerous Waste based on the corrosivity characteristic criteria.
- The reactivity (as cyanide and sulfide) was measured. Cyanide was not detected in any of the samples analyzed. Sulfide was detected in two samples, at concentrations of 330 mg/kg and 61 mg/kg. Results indicate low potential for designating as Dangerous Waste based on the reactivity characteristic criteria.
- TCLP result for all samples was less than the maximum allowable concentration of contaminants (Dangerous Waste threshold value). Therefore, the sediment does not designate as Dangerous Waste based on the toxicity characteristic criteria.

4.7.1.3 Dangerous Waste Criteria (WAC 173-303-100)

Wastes may be designated as Dangerous Waste based on criteria for toxicity and persistence. For the toxicity criteria, the waste must be evaluated either by a book designation process, or by biological testing methods. Applicable biological testing (including a static acute fish toxicity test or an acute oral rat toxicity test) has not been performed on Duwamish/Diagonal sediments. Book designation procedures require the determination of the toxic category for each known constituent, calculating an equivalent concentration, and comparing the result to applicable criteria.

Persistent constituents are chemical compounds, which are either halogenated hydrocarbons (HHs) or PAHs. The total concentrations of all detected HHs and all detected PAHs are determined by summing the concentration percentages for all HHs or PAHs that are known, and comparing the result to applicable criteria. The toxicity and persistence criteria will be evaluated in the design phase of the project.

4.7.2 Toxic Substances Control Act (TSCA) (40 CFR Chapter 1 Part 761.6)

Under TSCA, dredged materials that contain PCBs at concentrations of 50 ppm (wet weight) or greater shall be disposed of in an incinerator, at a chemical waste landfill, or by another agency-approved disposal method (40 CFR Sec. 761.6 (a)(3)(iii)(E)(5)). PCB concentrations were all less than the TSCA limit of 50 parts per million (ppm) (wet weight).

4.7.3 Total Petroleum Hydrocarbon (TPH)

The Phase 2 core sections were also characterized for TPH, since Ecology (1995b) guidance specifies appropriate soil end uses based on TPH levels. Sediment samples were analyzed for TPH using method WTPH-HCID to identify gasoline, diesel, and oil range TPH fractions. **Table 4.9** presents TPH testing results. TPH was detected in both cores analyzed. Concentrations ranged from 833 to 19,900 mg/kg diesel, and 3,160 to 20,800 mg/kg heavy oil. Gasoline was detected at 1,220 mg/kg only in the replicate 3 to 6 foot sections collected from Station DUD027.

Table 4.9 WASTE CHARACTERIZATION RESULTS

Sample ID	Dangerous Waste Regulations		DUD027		DUD027		DUD027-Rep.		DUD027-Rep.		DUD254		DUD254	
Laboratory ID			L8542-35		L8542-36		L8542-37		L8542-38		L8542-19		L8542-20	
Sample Depth (cm)			0-90		90-180		0-90		90-180		0-90		90-180	
Sample Date			5/21/1996		5/21/1996		5/21/1996		5/21/1996		5/21/1996		5/21/1996	
	DW	EHW	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.
Metals (mg/L)														
Arsenic, Total	5	500	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Barium, Total	100	10000	0.0818		0.0515		0.0819		0.198		0.14		0.222	
Cadmium, Total	1	100	0.003	U	0.0042	J	0.003	U	0.003	U	0.003	U	0.003	U
Chromium, Total	5	500	0.015	J	0.005	U	0.02	J	0.0094	J	0.007	J	0.0089	J
Lead, Total	5	500	0.03	U	0.03	U	0.03	U	0.03	U	0.418		0.03	U
Mercury, Total	0.2	20	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U
Selenium, Total	1	100	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Silver, Total	5	500	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U
Organics (ug/L)														
Benzene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Carbon Tetrachloride	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Chlordane	0.03	3	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
Chlorobenzene	100	10000	1	U	1	U	1	U	1	U	1	U	1	U
Chloroform	6	600	1	U	1	U	1	U	1	U	1	U	1	U
2-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
3-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
4-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.99		0.47	U
2,4-D	10	1000												
1,4-Dichlorobenzene	7.5	750	0.28	U	0.28	U	0.31	J	0.37	J	1.16		0.47	J
1,2-Dichloroethane	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
1,1-Dichloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
2,4-Dinitrotoluene	0.13	13	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U
Endrin	0.02	2	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor Epoxide	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Hexachlorobenzene	0.13	13	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U
Hexachlorobutadiene	0.5	50	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Hexachloroethane	3	300	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Gamma-BHC (Lindane)	0.4	40	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Methoxychlor	10	1000	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
2-Butanone (MEK)	200	20000	5	U	5	U	5	U	5.1	J	5	U	5	U
Nitrobenzene	2	200	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pentachlorophenol	100	10000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pyridine	5	500	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U
Tetrachloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
Toxaphene	0.5	50	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Trichloroethylene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
2,4,5-Trichlorophenol	400	40000	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,6-Trichlorophenol	2	200	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,5-TP (Silvex)	1	100												
Vinyl Chloride	0.2	20	1	U	1	U	1	U	1	U	1	U	1	U
WTPH (mg/Kg)														
Diesel Range (>C12 Thru C24)	NA	NA	2580		104		1310		19900		833		2010	
Gasoline Range (C7 Thru C12)	NA	NA	40	U	32	U			1220		28	U	31	U
Heavy Oil Range (>C24)	NA	NA	3540		244		2160		20800		3160		6250	
Conventionals														
Corrosivity (pH)	(2)	(2)	7.6		8		7.8		8		7.1		7.8	
Cyanide Reactivity (mg/Kg)	(2)	(2)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Flash Point (ºF)	(2)	(2)	160	>	160	>		TIA	160	>	160	>	160	>
Sulfide Reactivity (mg/Kg)	(2)	(2)	50	U	50	U	50	U	50	U	340		110	

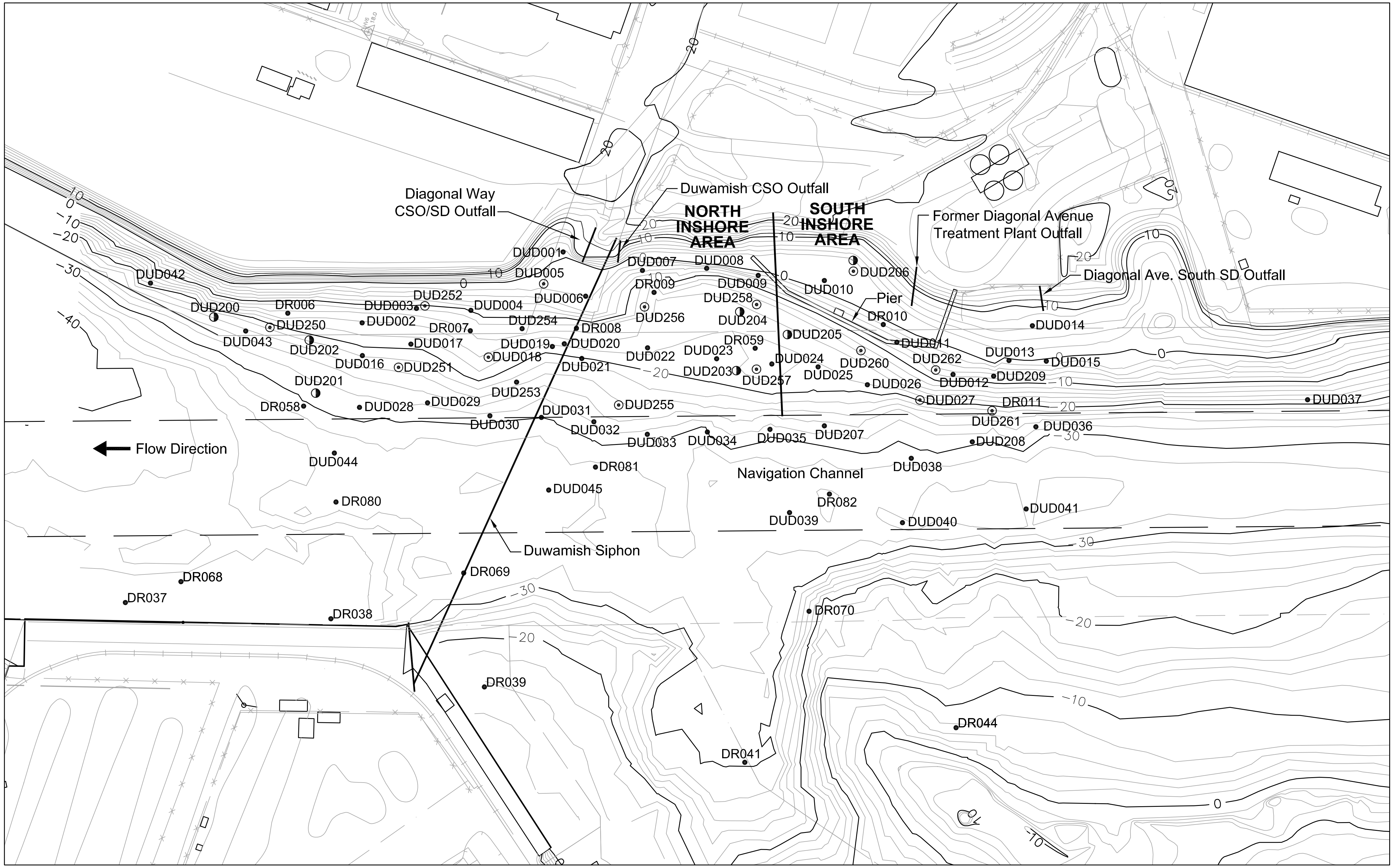
DW = Dangerous Waste

EHW = Extremely Hazardous Waste

NA = Not Available

(1) Chapter 173-303 WAC, Washington State Dangerous Waste Regulations, as amended November 1995.

(2) Narrative description in WAC 173-303-090.



—10— Bathymetry Elevation Contours in Feet (2-Foot Interval)

Sample Station Location
- Surface
- Bioassay
- Core

DUD001 EBDRP 1994 to 1996

DR006 EPA 1998

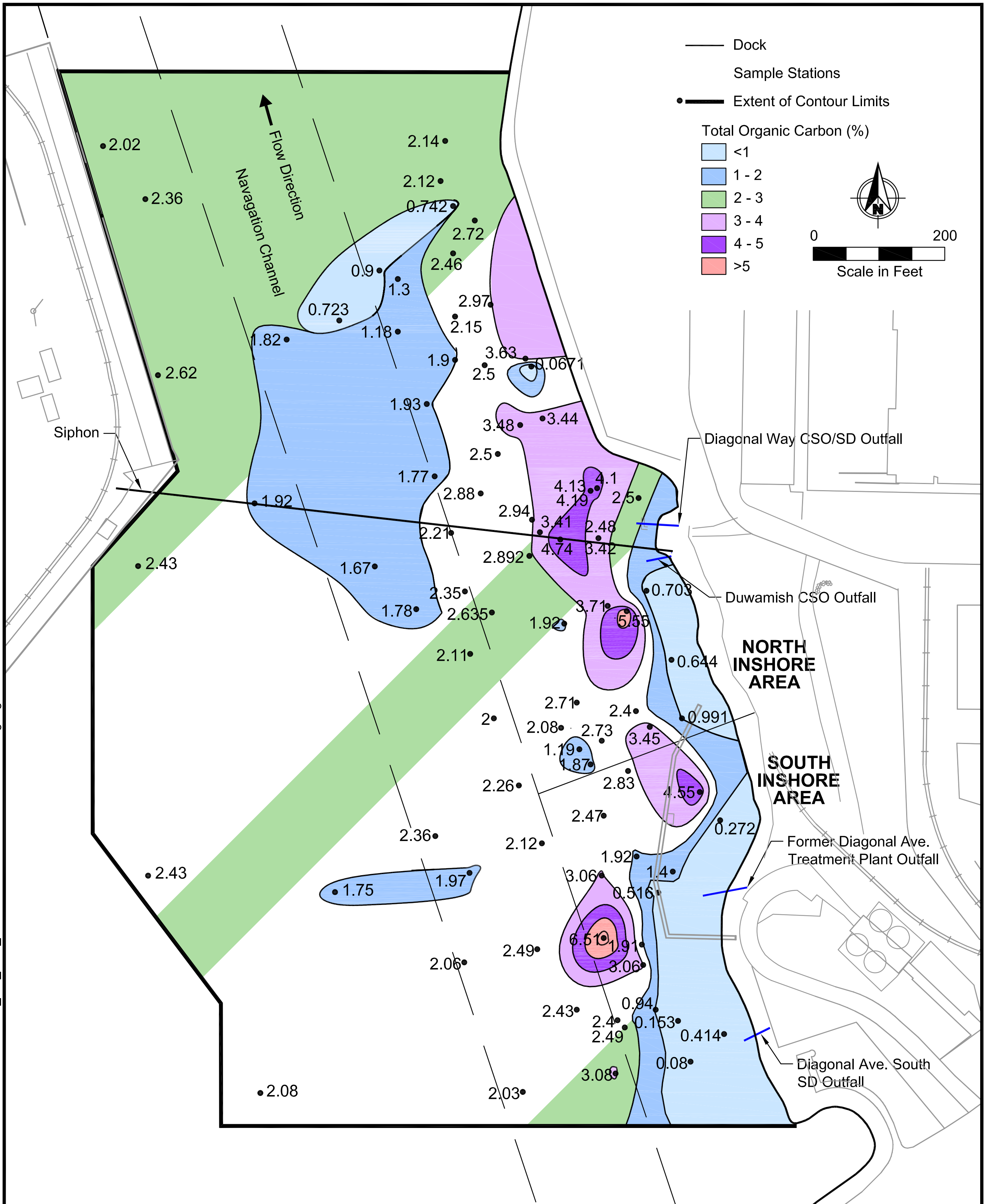
0 200
Scale in Feet

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

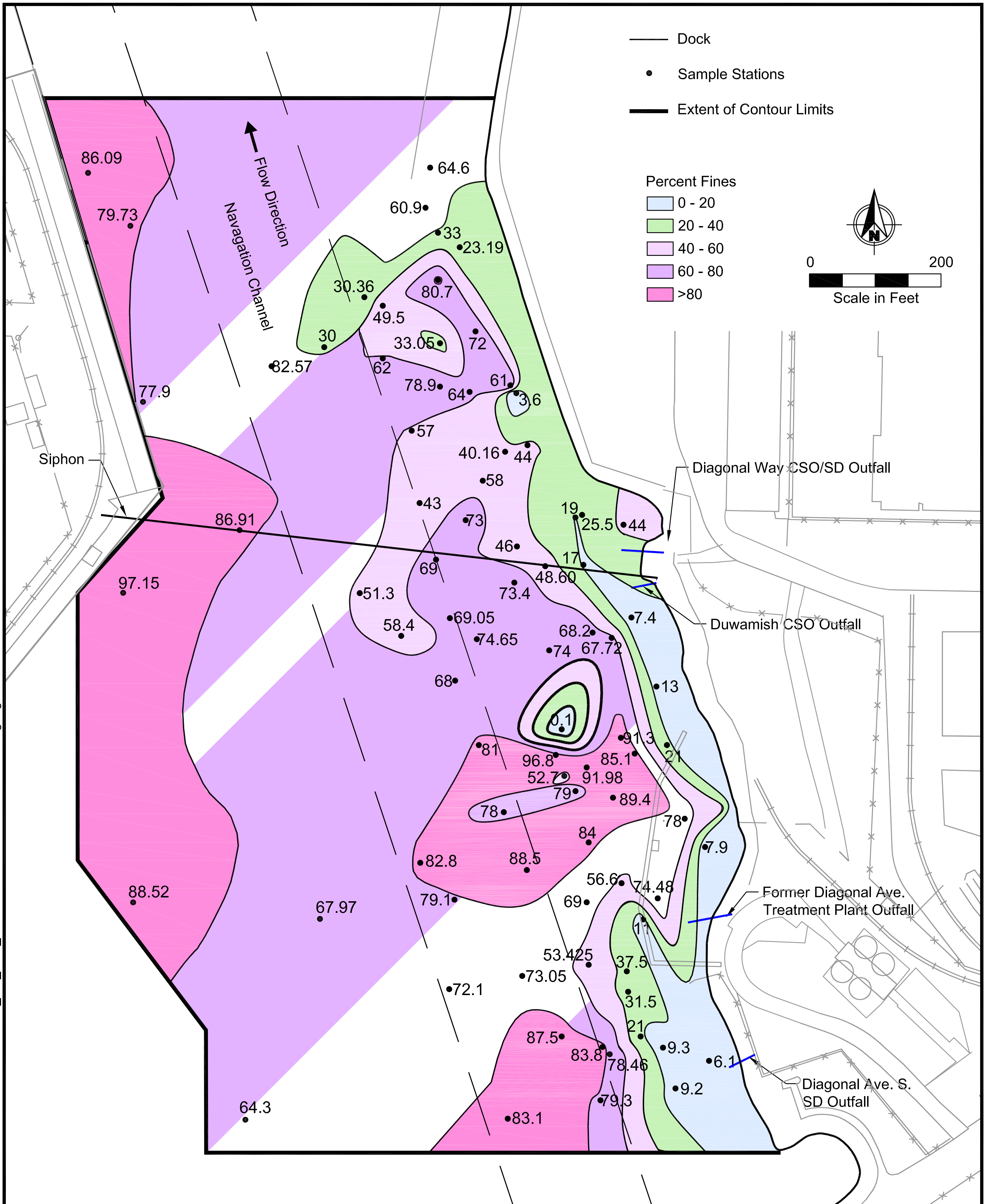
Sampling Locations

Figure 4-1



EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 4-2
	Surface Sediment Total Organic Carbon (%)	

Sep 28, 2005 3:05pm cdavidson K:\Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-59.dwg Fig 4-2 TOC

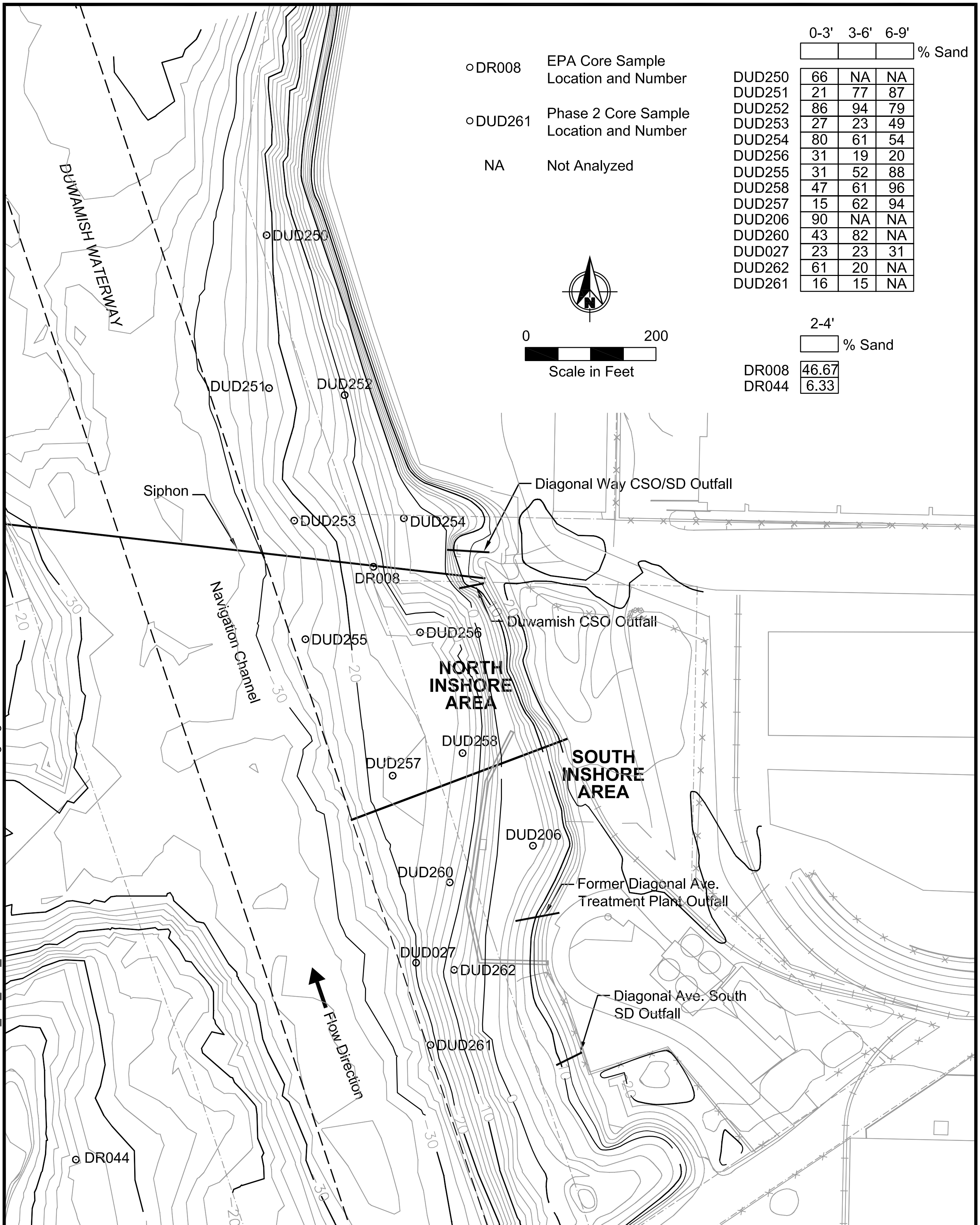


EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Surface Sediment Percent Fines

Figure 4-3



	0-3'	3-6'	6-9'
% Sand			
DUD250	66	NA	NA
DUD251	21	77	87
DUD252	86	94	79
DUD253	27	23	49
DUD254	80	61	54
DUD256	31	19	20
DUD255	31	52	88
DUD258	47	61	96
DUD257	15	62	94
DUD206	90	NA	NA
DUD260	43	82	NA
DUD027	23	23	31
DUD262	61	20	NA
DUD261	16	15	NA

	2-4'
% Sand	
DR008	46.67
DR044	6.33

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Percent Sand in Subsurface Sediments

Figure 4-4

Sep 28, 2005 3:08pm cdavidson K:Jobs\020067-KING_CO_SED_MANAG\02006701\02006701-61.dwg Fig 4-4